FINAL REPORT ON

CHARACTERIZATION AND TREATMENT OF COMBINED SEWER OVERFLOWS

(F.W.P.C.A. GRANT WPD-112-01-66)

SUBMITTED BY

THE CITY AND COUNTY OF SAN FRANCISCO

DEPARTMENT OF PUBLIC WORKS

PREPARED BY

ENGINEERING - SCIENCE, INC.

NOVEMBER 1967

CITY AND COUNTY OF SAN FRANCISCO
DEPARTMENT OF PUBLIC WORKS

DABEL

OFFICE OF THE
DIRECTOR OF PUBLIC WORKS

November 30, 1967

260 CITY HALL
SAN FRANCISCO
CALIFORNIA 94102

Federal Water Pollution Control Administration
Division of Research and Training Grants
633 Indiana Avenue
Washington, D. C. 20025

Gentlemen:

In conformity with the conditions contained in your grant to the City and County of San Francisco, No. WPD-112-01-66, "Feasibility of Control Measures for Treatment from Combined Sewers", I am pleased to transmit herewith our final report.

The report covers an evaluation of the laboratory and field results from the sampling of two combined sewage overflows representing 15% of the City's habitable area.

The results of the study established mass discharge factors for many of the biological and chemical constituents of combined sewage. A major development of the study was a clearer understanding of the quantity of each constituent as related to time after start of storm. I am sure that the information contained in the report will also be of significant interest to other communities with combined sewer systems.

Grateful acknowledgment is made to our consulting engineers, Engineering Science Inc., who performed the laboratory field work, and, in conjunction with my staff, prepared this report; to Doctor E. Pearson and Doctor W. Kaufman, professors of the University of California at Berkeley, who acted as technical advisors; and to the representatives of the State of California Department of Fish and Game, State Department of Public Health, and the State and Regional Water Quality Control Boards, who participated on a project advisory board that guided the direction of the study.

Also, I wish to express my appreciation to your agency for making this project possible.

Very truly yours,

S M Tatarian

S. M. Tatarian
Director of Public Works

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November 1967

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CHAPTER I

INTRODUCTION

Combined sewer overflows are recognized as one of the major water pollution problems in the United States today. Approximately half the urban population in the U.S. is served by combined sewer systems, and the situation in the City of San Francisco is very similar to that in other metropolitan areas. The City's sewerage system dates from an era in which sewage treatment was considered to be either unnecessary or economically infeasible. Sewerage was instituted for purposes of conveying any and all liquid wastes to points of convenient discharge. In the vicinity of San Francisco the bay and ocean were logical places to discharge municipal sewage and stormwater runoff. As a consequence, the quality of the waters adjacent to the City deteriorated extensively, and sewage treatment was instituted for purposes of improving the local aquatic environment. For economic reasons the combined sewer system was not replaced, and to this day during wet weather the discharge of untreated sewage along with surface runoff takes place.

The pollutional significance of combined sewer overflows has been magnified by the fact that during the wet season a few high intensity storms create an obvious esthetic degradation of the aquatic environment. With outdoor recreational activities occupying an increasingly larger portion of the urban population's time, public awareness of the pollutional effects engendered by overflows from combined sewers can certainly be expected to increase. Therefore, a recognition of the problem exists today and a mandate to resolve it is not far in the future.

At the time this investigation commenced, the recognition of the existence of serious pollution from combined sewer overflows had not resulted in systematic studies of the characteristics of such overflows and their pollutional significance; there had been little work directed toward a quantitative definition of the problem. Estimates of the problem were largely based upon the knowledge of the characteristics of urban sewage and the intuitive judgement that combined sewer overflows must be of a similar nature. Furthermore, it had been reasoned that the storage of materials in combined sewer systems during low flow periods was greater than that in separate systems because of the larger conduit sizes of the former, and that the storm flows removed the stored materials, resulting in a high degree of receiving water pollution.

Across the nation proposed solutions to the problem have been diverse. One solution receiving a great deal of attention and a certain amount of official support has been the obvious approach to separating combined systems. Although certain benefits can be anticipated from the conversion to separate systems, the engineering-economic feasibility of this solution for all communities has been challenged. Justification for other methods of solving the problem has likewise been fragmentary.

OBJECTIVES

The general objective of this study was to develop workable systems to manage overflows from the combined sewers of San Francisco, thereby alleviating pollution and protecting beneficial uses of local receiving waters, and to provide the rationale and methodolgy for controlling pollution from combined sewer overflows in other metropolitan areas of the United States. The specific objectives were:

1. To establish the relationships of quality and quantity of combined sewer overflows to the nature of the tributary area and to the normal dry weather sewage flow from the area.

2. To establish the influence of combined sewer overflows on the waters of San Francisco Bay, especially with regard to coliform bacteria.

3. To set forth methods of reducing the discharge of pollutants from combined sewers by means of appropriate treatment.

SUMMARY PROJECT DESCRIPTION

The preliminary phase of this study consisted of a description of the principal drainage districts, subdistricts, and major combined sewer outfall systems in the City and County of San Francisco for purposes of selecting pilot areas for intensive study. Two pilot systems were utilized: the Selby Street system and the Laguna Street system, so designated because of the location of their overflow outfalls.

The Selby Street system is comprised of a total area of about 3,400 acres, whereas the Laguna Street system is made up of an area of 350 acres. Both are mostly residential in nature, however few industries are located on the east side of Bay Shore Freeway in the Selby Street system. Eight storm overflows were monitored at the Selby Street outfall and two were monitored in the Laguna Street system. Monitoring included measurement of the rainfall and discharge as well as the quality characteristics of the overflows. The bacteriological impact of such overflows on receiving waters was determined by a coliform survey of a segment of the municipal marina adjacent to the Laguna Street outfall. Finally, laboratory tests were conducted for the purpose of selecting suitable methods for treating combined sewer overflows.

SUMMARY OF RESULTS

1. Analyses of the data collected during the study indicate that the concentration of various constituents in the overflows follow a distinct pattern, and it is postulated that the observed pattern can be divided into three phases, each of which is dominated by a single phenomenon. The initial phase is most probably caused by a flushing of sewage in the lower reaches of the sewerage system, and in general initial overflows have the characteristics of raw sewage. During the second phase, a systematic scouring of materials in the sewer and on the surface appears to take place, and an increase in the concentrations of the various pollutional constituents has been observed in most instances. Subsequently the concentrations drop to a steady level, which constitutes the third phase. The combination of relatively unpolluted surface runoff and the normal sewage flow make up the discharges during the third phase.

2. The time of decrease to a steady level, or decay time, has been found to be remarkably constant and virtually independent of the system physiography and the meteorological conditions.

3. The mass discharges of the various constituents in primary treatment effluent, combined sewer overflows, and urban storm runoff are shown in Table I-1. It can be seen that as compared to primary effluents, combined sewer overflows and urban storm runoff contribute only small amounts of pollutants to the receiving waters. Differences between the discharges of combined sewer overflows and urban storm runoff are relatively very small. This seems to indicate that the separation of sewers would not result in any significant reduction in the incidence or magnitude of pollution of receiving waters.

4. The receiving water studies demonstrated that coliform levels in waters proximate to combined sewer outfalls are significantly affected by wet weather discharges. It has been concluded that disinfection of combined sewer overflows will be necessary if receiving waters are to meet existing recreational water quality requirements.

5. Treatment of combined sewer overflows appears to be the most feasible solution to the pollutional problems caused by such discharges. For communities such as San Francisco, the separation of combined sewer systems constitutes one of the more costly alternatives. The dissolved air flotation process in conjunction with chlorination is indicated to be an effective method for treating the overflows.

6. Based on the results of the present study the following recommendations are made:

a. The present study should be continued in order to assess the relative mass emission rate of pollutants contributed by surface runoff with respect to the pollution originating as a result of sanitary sewage. In addition an evaluation of the impact of the discharge of combined sewers on the aquatic environment should be made. It would also be desirable to conduct laboratory experiments to determine the efficacy of the use of chemical additives as a part of the treatment of overflows by means of dissolved air flotation. Further analysis of the pattern and distribution of rainfall in relation to the resultant pollutional effects would also be worthwhile.

b. A small treatment facility should be constructed to treat the overflows from one of the minor outfalls of the City. The treatment process should consist of dissolved air flotation and chlorination. The Baker Street outfall in the northern shoreline of the City seems most suitable for this demonstration because of its relatively small watershed size (167 acres) and because the benefits accrued will be substantial in that the receiving waters in this area have an intense recreational use.

TABLE I-1

ANNUAL MASS DISCHARGES (lb/acre-yr)

Constituent	Primary Effluent		Combined Sewer Overflows		Separate + Storm Sewer Discharges	
	Selby	Laguna	Selby	Laguna	Selby	Laguna
BOD	1,450	4,050	101	136	25	29
COD	2,420*	6,750*	447	480	188	218
SS	1,415*	3,970*	632	538	570	~ 500
VSS	900	2,780	146	224	125	145
Grease	344	965	36	41	...	...
N	250*	792*	10.6	15.6	7.0	8.2
PO_4	262*	830*	2.4	3.2	2.0	2.3

* Assumptions:
BOD:COD = 0.60
VSS:SS = 0.70
N = 35.7 mg/l
PO_4 = 37.5 mg/l

Per Capita Flows
Selby - 96 gcd
Laguna - 107 gcd

\+ Calculated from Mass Discharge Factors from Cincinnati (See Table V-7) and annual runoff in the two pilot sectors in San Francisco.

MANAGEMENT OF THE STUDY

The study was undertaken at the request of the City and County of San Francisco, Department of Public Works, Mr. S. Myron Tatarian, Director; Mr. Clifford J. Geertz, City Engineer, served as Project Director. All aspects of the investigation were under the direct supervision of the Deputy Project Director, Mr. Alan O. Friedland, Head of the Sanitary and Special Projects Section, Bureau of Engineering. Assisting Mr. Friedland were Mr. Louis A. Vagadori and Mr. Ronald Ciraulo of the Bureau of Engineering, and Mr. Keeno Fraschina of the Bureau of Sewer Repair and Sewage Treatment.

Special consultants to the City were Dr. Erman A. Pearson and Dr. Warren J. Kaufman of the Division of Hydraulic and Sanitary Engineering, Department of Civil Engineering, University of California, Berkeley.

In order to secure the guidance and counsel of eminent persons in the water pollution field, a Project Advisory Committee was formed. It consisted of the following individuals:

Paul Bonderson, Executive Officer, California State Water Quality Control Board
  Alternate: Mr. George Gribkoff
John B. Harrison, Executive Officer, San Francisco Bay Regional Water Pollution Control Board
  Alternate: Mr. Fred Dierker
S. Myron Tatarian, Director of Public Works, City and County of San Francisco
Henry Ongerth, Assistant Chief, Bureau of Sanitary Engineering, State of California, Department of Public Health
Jack Frazier, Chief of Water Projects Branch, State of California, Department of Fish and Game
Harvey F. Ludwig, President, Engineering-Science, Inc.

The Project Advisory Committee convened at pertinent times during the course of the investigation, and its members made many valuable suggestions related to the conduct of the study.

ACKNOWLEDGEMENTS

The Jewish Home for the Aged very graciously allowed the project rain gauge to be set up on the roof of the Home. Collecting the data involved many trips through the Home, however, in every instance the project personnel were well received. Our appreciation is extended to Mr. Sidney Friedman, Executive Director of the Jewish Home for the Aged, and to his excellent staff.

This investigation was funded in part by the Federal Water Pollution Control Administration through Research and Demonstration Grant No. WPD-112-01-66.

CHAPTER II

PREVIOUS STUDIES

Until recently, investigation of the quality characteristics of combined sewer overflows had not received a great deal of attention in the United States. Only scattered reports appear in the sanitary engineering literature and these are in general devoted to the hydraulic and hydrologic aspects of combined sewers. Very few of the reported studies have incorporated an evaluation of the quality characteristics of combined sewer overflows and in no known instance have comprehensive monitoring programs been conducted. On the other hand, a qualitative picture of the principal phenomena associated with combined sewer overflows can be constructed on the basis of the published reports dealing with surface runoff and information on the dry weather sewage characteristics.

SURFACE RUNOFF FROM URBAN AREAS

A number of investigators have recognized that simple urban storm runoff is a significant factor in pollution associated with combined sewer overflows (1, 2, 3, 4, 5, 6, and 7). Table II-1, prepared by the Public Health Service (8), summarizes certain of the findings. Examination of Table II-1 leads to the conclusion that significant quantities of major pollutional constituents are entrained in runoff from urban areas. However, there has been no known attempt to assess the relative contribution of surface runoff to the aggregate pollutional content of combined sewer overflows. Interest in such information is more than academic. As a prerequisite to the design of control systems or treatment processes for combined sewer overflows, it is essential that the problem be well understood in terms of the character of the major inputs.

Weibel (7) has presented results from a monitoring of urban surface runoff in Cincinnati and his study has represented the most comprehensive effort of this nature undertaken to date. Data were collected over a two-year period using automated sampling equipment. During this period a wide range of meteorological conditions were experienced and the conclusions developed are probably applicable to urban areas of similar characteristics.

Table II-2 illustrates Weibel's calculations of mean concentrations of various constituents in urban land runoff as a function of time. It was not evident that there was a significant relationship between antecedent dry period and the quality of urban surface runoff.

Based on his hydrologic and urban runoff quality data, Weibel calculated the annual mass discharge of various constituents in urban surface runoff. These values are shown on the following page. Weibel concluded that urban surface runoff cannot be neglected in considering waste loadings from urban sources.

TABLE II-1

CHARACTERISTICS OF SURFACE RUNOFF FROM URBAN AREAS (8)

Constituent	Seattle, Washington	Oxney, England	Moscow U.S.S.R.	Leningrad, U.S.S.R.	Stockholm, Sweden	Pretoria, S.Africa Park Area	Pretoria, S.Africa Business District
BOD (mg/l)	10	100(max)	18-285	36	17-80	30	34
COD (mg/l)					18-3100	29	28
Total Solids (mg/l)					30-8000		
Susp. Solids (mg/l)		2,045	1,000-3,500	14,541			
Coliform (MPN/100 ml)	16,000				40-200,000	240,000	230,000
Org.-N (mg/l)	9.0(max)					5.4	3.5
NO_3-N (mg/l)	2.8(max)						
Soluble P (µg/l)	784(max)						
Total P (µg/l)	1,400(max)						
Fixed Residue (mg/l)					210-2420		
Dissolved Solids (mg/l)						228	154

TABLE II-2

MEAN CONCENTRATIONS OF CONSTITUENTS IN URBAN LAND RUNOFF, CINCINNATI, OHIO (7)

Constituent	Time after start of runoff 0-15 min	15-30 min	30-60 min	60-120 min	120 min and over
SS, mg/1	390	280	190	200	160
VSS, mg/1	98	69	47	58	38
COD, mg/1	170	130	110	97	72
BOD, mg/1	28	26	23	20	12
Total Nitrogen -N, mg/1	3.6	3.4	3.1	2.7	2.3
PO_4 (total soluble as PO_4) mg/1	0.99	0.86	0.92	0.83	0.63

ANNUAL MASS DISCHARGE OF CONSTITUENTS IN URBAN SURFACE RUNOFF, CINCINNATI OHIO

Constituent	Annual Discharge (lbs/Acre per Year)
Suspended Solids	730
Volatile Suspended Solids	160
Chemical Oxygen Demand (COD)	240
Biochemical Oxygen Demand (BOD_5)	33
Total Kjeldahl Nitrogen	8.9
Phosphate (PO_4)	2.5

COMBINED SEWER OVERFLOWS

The characteristics of combined sewer overflows have been analyzed to various degrees by a number of investigators. In most cases, however, it is not possible to develop a scientific explanation of system behavior from the reported data.

Palmer (1) published results from a series of observations in Detroit. His conclusion was that combined sewer overflows in that city have the following "average" characteristics:

Constituent	Concentration
Total Coliforms (MPN)	4,300,000 per 100 ml
5-day BOD	50 mg/1
Suspended Solids	250 mg/1
Volatile Suspended Solids	100 mg/1

Dunbar and Henry (9) have published similar data from several locations. These data are presented in Table II-3.

Limited data on suspended solids discharges in combined sewer overflows have been published by Romer and Klashman (10). They report the following data from Sheffield and Heywood, England:

Time after Commencement of Overflow - Hours	Suspended Solids - mg/1	
	Sheffield	Heywood
0	592	2380
1	602	1100
2	671	690
3	1701	500
4	1259	380
5	1335	830
6	1012	280
7	1006	180
8	979	
9	417	
10	401	
11	263	

TABLE II-3

CHARACTERISTICS OF COMBINED SEWER OVERFLOWS (9)

City	Coliform (MPN/100 ml)	Total Solids (mg/1)	Suspended Solids (mg/1)	BOD (mg/1)
Buffalo N.Y.	-	-	172 to 1,220	-
Buffalo N.Y.	-	498 to 754	158 to 544	100 to 162
Buffalo N.Y.	-	461 to 785	126 to 436	121 to 127
Toronto Ont.	23,000 to 2,400,000	-	130 to 930	40 to 260
Toronto Ont.	70,000 to 3,500,000	-	17 to 580	0 to 100
Welland Ont.	210,000	850 to 960	168 to 426	220 to 614

In 1963 Gameson and Davidson (11) published results of the first known attempt at a comprehensive study of the variations in quantity and quality of combined sewer overflows. Figure II-1 is a plot of a data summary presented by Gameson and Davidson (Table 6 of that paper).

The data plotted represent long term weighted averages, hence the usually reported very sporadic initial readings are not indicated. In considering these data, it must be kept in mind that the reliability of the early data is much more questionable than that of the latter. In general, however, three periods seem to be defined. The initial flushing of loose and light materials trapped in the sewers and on the surface probably followed by a systematic scouring of the interior of the sewer, finally, converging to a condition of simple mixing of flows. However, the magnitude and duration of each phase may be unique to each system.

Table II-4 compares the characteristics of combined sewer overflows and storm sewer overflows in Oakland, California (8). Both storm water and combined sewer overflows contain substantial pollutional loads as measured by the classical standards. Differences seem to be most significant with respect to the number of coliforms present as might be expected.

TREATMENT OF COMBINED SEWER OVERFLOWS

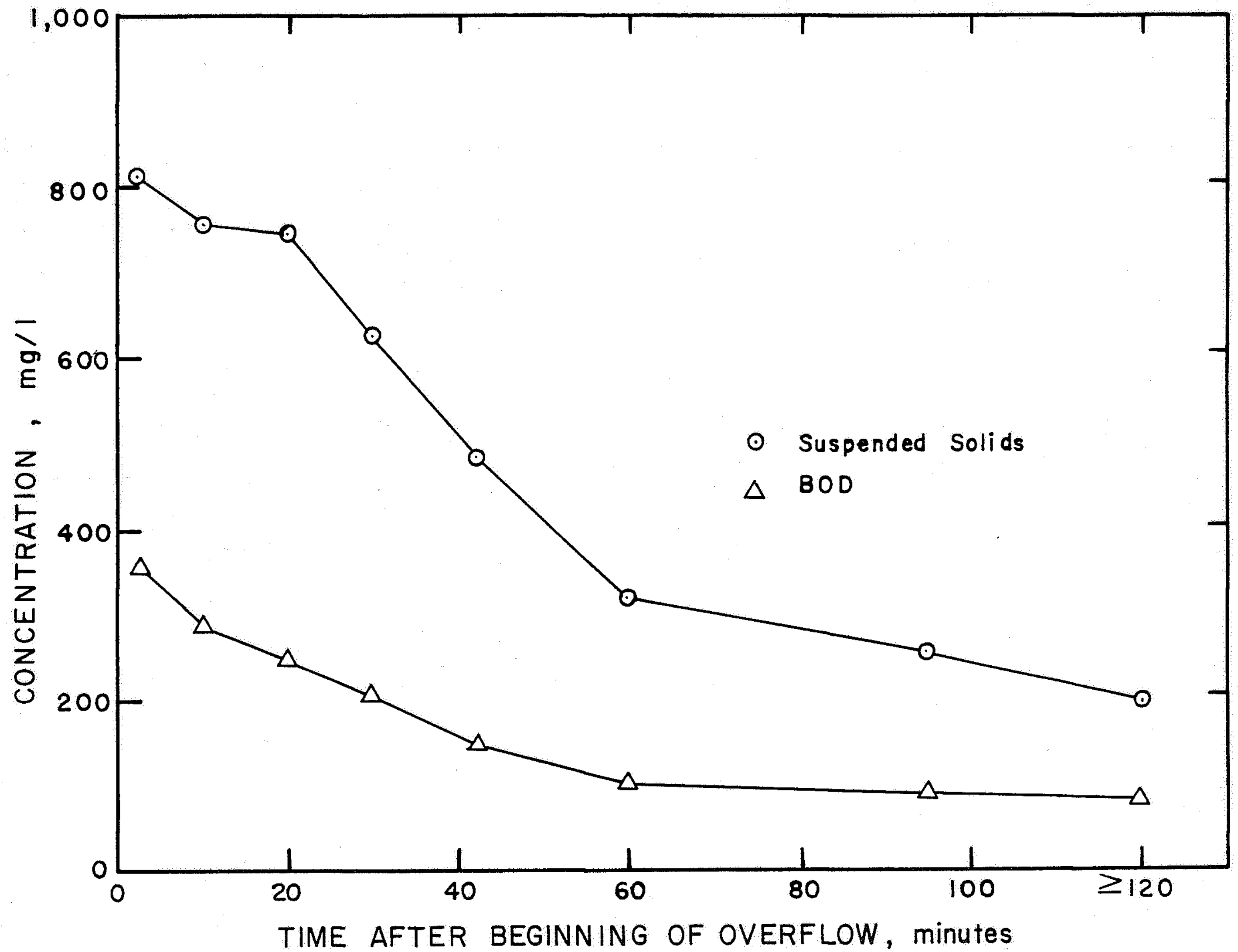
Treatment of combined sewer overflows has characteristically consisted of the diversion of lesser flows to conventional treatment plants with no effort being given to deal with the larger flows. Storage of various fractions of overflows has been considered in several communities, such as Chicago (12) and New York (13). However, as previously mentioned, design criteria in most instances appear to have been developed solely on hydrologic considerations.

TABLE II-4

CHARACTERISTICS OF COMBINED SEWER

OVERFLOWS AND STORM WATER AT OAKLAND (8)

Determination	Combined Sewer Overflows (14 samples from various stations)			Storm Sewer Flows (21 samples from various stations)		
	Minimum	Maximum	Average	Minimum	Maximum	Average
DO (mg/l)	2.4	9.6	6.9	0	13.2	7.3
BOD (mg/l)	13	153	59	3	>700	87
Total Solids (mg/l)	132	1,327	400	726	726	1,401
Vol. Solids (mg/l)	83	291	144	168	168	168
Susp. Solids (mg/l)	60	1,120	203	16	4,400	613
Coliform (MPN/ml)	2,300	2,400,000	293,000	4	70,000	11,800
Chlorides (mg/l)	619	619	619	300	10,260	5,100
Oil & Grease (mg/l)	8	66	33	2	162	32
Sand (mg/l)	0	276	76	7	868	158
pH	6.8	7.4	7.1	6.3	7.8	6.9



CONSTITUENT CONCENTRATION VARIATIONS IN COMBINED SEWER OVERFLOWS NORTHAMPTON, ENGLAND (II)

FIGURE II - I

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CHAPTER III

DESCRIPTION OF STUDY AREA AND MAJOR OUTFALLS

INTRODUCTION

The first comprehensive study and plan for the overall sewerage of the City of San Francisco was undertaken in the 1890's, and construction of a planned system of main sewers and interceptors began about 1910. At that time the need for sewage treatment was not anticipated, and a system of combined sewers was considered to be the most reasonable method for the conveyance of sanitary wastes, industrial discharges, and storm runoff. The discharge points were located at convenient points along the entire periphery of San Francisco.

As a result the conditions of the bay and beach areas rapidly deteriorated, and the City initiated engineering studies for waste treatment in 1935. Since that time San Francisco has constructed interceptor sewers which collect all the dry weather flow. Primary treatment is carried out at three locations and after chlorination the effluent from these plants is discharged to the receiving waters. Current plant capacity allows the treatment of runoff from 0.02 inch of rain per hour, which is equivalent to about twice the normal dry weather flow (the design interceptor ratio is 3:1) but amounts to only two percent of the design capacity of the storm drain system. Thus, under conditions of heavy runoff, a mixture of storm water and sewage bypasses treatment and is discharged to the receiving waters.

The City's Department of Public Works had estimated that the cost of constructing a separate sewer system would be $1.4 billion (including bond redemption, engineering, and a 30-year construction period), or about $25,000 per acre of habitable land on a present worth basis. Consequently, the City instituted a program to explore the possibility of an alternative solution to the problem. It was the objective of this program to provide information for purposes of developing a workable system to treat the overflows from the combined sewer system.

This chapter contains a description of those elements of the City's sewerage system and treatment facilities which are pertinent to the evaluation of the problems engendered by combined sewer overflows.

DRAINAGE DISTRICTS

As shown in Figure III-1, the City of San Francisco is divided into three districts for purposes of sewerage and sewage treatment. Because the entire sewerage system is combined, these districts also comprise discrete watershed areas for storm runoff. A more detailed map of the sewerage system is included inside the back cover of this report.

Richmond-Sunset District

This area lies on the western side of San Francisco and comprises an area of about 9,500 acres, not including the public lands west of Lake Merced, the beach areas, Lincoln Park, and the Presidio. Figures III-2, III-3, and III-4 show that the principal land use is residential, with the usual commercial establishments appearing along the major thoroughfares. These data were obtained from a land use survey conducted by the San Francisco Department of City Planning in 1964 and are based on ground floor usage. Hence, an area indicated as commercial might, in addition, serve residential purposes above the ground floor. The 1960 population figure was 215,000 and by 1980 it is expected to reach 250,000. The design ultimate population for this district is 280,000.

Although Twin Peaks at an elevation of about 800 feet is the actual eastern boundary of the district, for practical purposes the sewerage service begins at a much lower elevation, nominally about 400 feet. In general, the sewers flowing from east to west have relatively steep grades. Consequently there is little problem with fouling in these systems.

This area is served by the Richmond-Sunset Sewage Treatment Plant located at the western end of Golden Gate Park near Lincoln Way. The design dry weather capacity of this plant is 22.5 mgd and the average flow during June 1966 was 19 mgd. The design storm flow capacity of this plant is 70 mgd. The plant provides primary treatment with post-chlorination of the effluent before discharging the effluent into the ocean near Mile Rock, which is off the northwest tip of San Francisco. The sludge is digested and filtered for use by the City Park Service as a soil conditioner.

Receiving water uses along the ocean boundaries of the Richmond-Sunset District are largely recreational. According to a 1965 survey, 80 percent of the total ocean beach usage is confined to the area between Cabrillo and Vicente Streets. As shown in Figure III-5, there are six major storm water overflows in the Richmond-Sunset District. Two of these terminate on the Cabrillo Vicente Beach, and all are in close proximity to beach sites. It is believed that the recreational uses of the beach areas will increase in the near future.

North Point District

This district encompasses 9,000 acres in the northeastern corner of San Francisco and includes the entire downtown section as well as much of the industrial park area located south of the Bay Bridge Skyway.

As is evident from Figures III-2, III-3, and III-4 land usage is quite diversified. The present population of this area is 487,000 and the ultimate design estimate is 835,000. The north central section of the district will be the site of extensive high rise apartment construction.

Except in waterfront areas, the slopes of the sewers are relatively steep and fouling usually occurs only as a result of specific industrial discharges.

The dry weather design capacity of the plant (primary treatment with post-chlorination) is 65 mgd. The average flow for June 1966 was 54 mgd. There are no sludge digestion facilities; sludge is pumped through a six mile force main to the Southeast Plant for digestion and disposal. Grit and screenings are hauled to a sanitary landfill site. During storm flow periods, the plant will accept a flow up to 150 mgd.

The outfall system branches into four separate outlets. Two of these terminate at the end of Pier 33 and two at the end of Pier 35. The end of the piers are approximately 1,000 feet offshore. Each outlet is terminated with a 45 degree elbow, and discharges 10 feet below mean lower low water downward into approximately 30 feet of water.

Generally receiving water usage varies from water contact sports in the Marina and Aquatic Park areas to ship berthing and fishing in the vicinity of Central Basin. It is anticipated that the beneficial uses will be altered substantially in the near future, and water quality standards will be much more stringent.

Five major storm water overflows serve the North Point District. Two of these spill into the recreational areas of the Marina while two others are located along the Embarcadero. The fifth and largest discharges into the head of China Basin.

Southeast District

The Southeast District covers approximately 7,100 acres of residential and industrial land. Current and design population estimates are 161,000 and 400,000 respectively. There are very few commercial establishments in this district. As shown in Figure III-4, the industrial activity is confined to the area east of the Bayshore Freeway. Among the industries located in this zone, there are several which produce troublesome discharges: meat packing plants, tanneries, rendering plants, wool pulling operations, poultry processing, paint manufacturers, breweries, etc. Many of the industries operate on a batch basis and discharges often occur in slugs, this being reflected by analyses made at the treatment plant, which have shown that pH and BOD pulses appear frequently at the headworks.

In the residential areas the sewers have adequate grades. However, in the industrial zone many are relatively flat and prone to fouling. The Southwest sector of this district, discharging at Selby Street, is unique for San Francisco as the time of concentration - approximately 50 minutes - is the longest of any sector in the city.

The Southeast Treatment Plant is located in the heart of the industrial area just south of Islais Creek. Primary treatment and chlorination are practiced, and the effluent is discharged to Islais Creek near the Third Street Bridge. The dry weather design capacity of the plant is 30 MGD and current dry weather flow is about 17 MGD. The hydraulic capacity of the plant has been restricted to 30 MGD, but plant modifications now underway expected to increase this capacity to 70 MGD.

Receiving water uses in this locale are restricted almost entirely to ship berthing, although some fishing takes place in the deeper waters.

There are four major storm water outfalls in the Southeast District. Two of these are located at the head of Islais Creek (Marine Street and Selby Street) and the others discharge in the vicinity of Candlestick Park.

FLOW CHARACTERISTICS

Dry Weather

The main trunk sewers for each district are shown with the district boundaries in Figure III-1. These define the dry weather flow patterns as well as those of wet weather up to the points of bypass.

In the Richmond-Sunset District all flows converge at the plant near the foot of Lincoln Way. A portion of the flow from the Lake Merced area is conveyed to the Vicente Street trunk at 34th Avenue. A pumping station west of the Lake receives some of the sewage from this area through the old storm flow line to the south of the lake and pumps it to Vicente Street near 44th Avenue.

In the southern portion of the Richmond-Sunset District flow is by gravity to the point of convergence on Lincoln Way. The eastern half of the Richmond district, however, slopes to the northwest and, during dry weather flows proceeds to Lake and 26th Street. From there a tunnel carries the sewage to Fulton and 25th Avenue, where it joins the other flows from the north before entering the plant.

The average per capita volume contribution is about 90 gallons per day, and analyses made at the plant show the characteristics of the dry weather flow to be representative of normal domestic sewage. Average results of samples taken during June 1966 were:

5-day BOD*	210 mg/1
Suspended Solids*	213 mg/1
Grease*	44 mg/1
Sand	171 cu ft/day
Screenings	64 cu. ft/day

* 24-hour composite samples

The North Point Plant is the terminous of two trunk systems. To the west the natural drainage pattern is north, and flows originating in this zone are intercepted at the foot of Pierce Street from which point they are pumped directly to the plant. Dry weather discharges from the remainder of the district are ultimately transported via the North Point Main which lies beneath Sansome Street north of Market. Slopes in the western downtown area are generally southeasterly, thus the flow from this sector to the plant proceeds in a counterclockwise fashion. Not shown in Figure III-1 is an interceptor which lies along Berry Street north of China Basin. This line picks up flows which until recently discharged into the basin.

The effects of industrial-commercial establishments with respect to volume of flow are evident. The average in the North Point District is about 110 gallons per capita per day. The strength characteristics are higher than in the Richmond-Sunset District. Average values of composite samples taken at the treatment plant during June 1966 are shown below:

5-day BOD *	275 mg/l
Suspended Solids *	242 mg/l
Grit	162 cu. ft/day
Screenings	216 cu. ft/day

* 24-hour composite samples

In the Southeast District the area south of McLaren Park is served by a trunk system which carries the flows to a point just east of the Bayshore Freeway. From that point a tunnel conveys the dry weather flows beneath Bay View Park to a pumping station at Yosemite Avenue and Ingalls Street. The sewage is mixed with that originating to the west of the pumping station and the mixture flows through another tunnel beneath the hills of Hunters Point and continues to the treatment plant. From the west the principal trunk closely follows the route of the Southern Freeway, collecting all the wastewater from this region. It continues along the right-of-way of the new Embarcadero Freeway to the head of Islais Creek at the Selby Street Diversion Structure, where the interceptor sewer collects the dry weather flow. All discharges from points north converge at the Marin Street Diversion structure, which is also at the head of Islais Creek. The interceptor passes from there through the Selby Street outfall and directly to the treatment plant.

Per capita flows are normal for San Francisco (94 gpcd) due to the preponderance of residential land use. However, there are several industries discharging relatively concentrated wastes and this is reflected in the characteristics of the plant influent. Average data from the Southeast Plant for May 1966 are given below:

5-day BOD	261 mg/l
Suspended Solids	330 mg/l
Grease	91 mg/l

Wet Weather

Data obtained from the U. S. Weather Bureau indicate the rainfall patterns are relatively uniform over San Francisco. There are three official gauging stations in the vicinity: the Richmond-Sunset in Golden Gate Park, the Federal Office Building downtown, and the International Airport located about 10 miles south of downtown San Francisco. Rainfall data reported by these stations are compared in Table III-1.

The storm flows reported in this chapter have been computed by the Rational Method using coefficients of runoff supplied by the City. Rainfall intensities were obtained from U. S. Weather Bureau frequency analyses, which had been calculated by the Method of Extreme Values (after Gumbel) and based on 47 years of data (1903-1950) from the Federal Office Building Weather Station (Figure III-5).

TABLE III-1

COMPARISON OF RAINFALL DATA FROM
OFFICIAL GAUGING STATIONS IN OR NEAR SAN FRANCISCO

Station	Federal Office Building	Richmond-Sunset	International Airport
Years of Record	117	8	39
Annual Rainfall (Inches)			
1966	16.45	17.53	15.98
1965	19.86	21.94	21.22
1964	17.73	16.89	17.54
1963	18.78	21.00	19.89
1962	19.99	23.24	24.25
1960	17.82	17.80	16.90
Average of Above	18.44	19.73	19.30
Long Term Mean	20.78	-	18.69

For purposes of runoff calculations the 5-year storm of appropriate duration was employed and the results are shown in Figure III-1. The relationship between the storm water discharges from each district and the return period is shown in Figure III-6. These discharges have been calculated using the data shown in Figure III-5 and with the assumptions indicated in Figure III-6.

In the Lake Merced area only 5 percent of the storm water presently flows north toward the treatment plant. From three overflow structures 960 cfs bypassed to the outfall (#1) (see Figure III-1). The small flow moving north (approximately 30 cfs) joins that from the tributary system of the Vicente Street trunk. Approximately 1000 cfs overflows at Vicente Street and 45th Avenue and continues to the outfall on the beach (#2) with very little flow moving northward to the treatment plant.

At the junction of interceptors at the Lincoln Way Diversion structure, the total flow is approximately 1800 cfs. Due to the relatively small capacity of the Richmond-Sunset Treatment Plant, nearly the entire flow is diverted to the ocean at the foot of Lincoln Way (#3).

In the northeastern regions of the Richmond-Sunset District the trunk sewer flows west on Lake Street. At the first diversion at Lake Street and 17th Avenue the combined flow is 900 cfs and approximately 800 cfs is diverted to the outfall on Bakers Beach (#6). At 22nd Avenue and Lake Street there is another diversion which also discharges to Bakers Beach. The capacity of the overflow is about 400 cfs, which gives a total flow of 1200 cfs at the Bakers Beach outfall (#6). The last overflow carrier in this vicinity begins at 25th Avenue and Lake Street and terminates at the Seacliff Outfall (#5). The remainder of the area north of Golden Gate Park is drained to the treatment plant outfall which terminates offshore near Mile Rock (#4).

From the area north of the Marina and Aquatic Park a total runoff of 1050 cfs has been calculated. Approximately 400 cfs spills from the Laguna Street Trunk (#8), and the remainder is distributed between the outfalls on Baker Street (not shown) and Pierce Street (#7). The latter handles approximately 70 percent of the remaining flow. The Beach Street overflow receives storm water principally from the adjacent land area and an additional amount from the Marina Pumping Station. It is estimated that its discharge is about 550 cfs.

The complexity of flows in the remaining sections of the North Point District do not permit an accurate estimation of locations and magnitudes of storm water overflows. Calculations show the total runoff to be approximately 3900 cfs, and 70 percent of this, or 2700 cfs, is discharged from the Seventh Street Diversion into China Basin (#11).

Near Islais Creek in the Southeast District, runoff from the north focuses at the Marin Street overflow (#12). The storm water flow at Marin Street is about 1175 cfs. Because of the Selby Street overflow downstream on the interceptor, nearly all of the flow discharges at the Marin Street overflow structure. The Selby Street Diversion terminates a much larger sewer system and the flow at this point has been calculated to be 1800 cfs. It is estimated that greater than 95 percent of this will spill directly to Islais Creek (#13).

From the Visitacion Valley area the storm water contribution is about 600 cfs. The overflow structure at Sunnydale Avenue (#15) was designed to bypass this flow. Other contributions from the lands south of the treatment plant amount to 1300 cfs. The greater portion of this flow, perhaps as much as 90 percent, is bypassed at Yosemite Avenue.

OUTFALL SURVEY

This section describes the major outfall systems in San Francisco. The outfalls have been classified as major if their discharge is more than 500 cfs during a 5-year storm.

As previously mentioned, there are 15 major stormwater discharge points in the three districts; these are:

District	Number	Overflow Location	Nominal Discharge (cfs)*
Richmond-Sunset	1	Lake Merced	960
	2	Vicente Street	1000
	3	Lincoln Way	1800
	4	Mile Rock	1145
	5	Sea Cliff	520
	6	Bakers Beach	1200
North Point	7	Pierce Street	460
	8	Laguna Street	400
	9	Beach Street	550
	10	Jackson Street	600
	11	Seventh Street	2700
Southeast	12	Marin Street	1175
	13	Selby Street	1800
	14	Yosemite Street	1170
	15	Sunnydale Avenue	600

* Equaled or exceeded on 20 percent of the years, i.e., with a recurrence interval of 5 years.

The outfalls are numbered in succession, beginning at the southwest corner of the city and proceeding clockwise around the waterfront area as shown in Figure III-1. Pictures of most of the outfalls are shown in Figures III-8 through III-13 in the order in which they are described in this section. Some structures are not shown due to their inaccessability. Included with the descriptions are evaluations of the suitability of the outfalls for monitoring purposes. The following criteria were applied in making the evaluations.

1. The watershed should be well defined in terms of contributing discharges.

2. The results obtained from the study should, as far as is practical, provide a basis for the characterization of storm water flows from other areas of the city and similar areas in other cities in the United States.

3. The outfall structure should be readily accessible and amendable to wet weather sampling and flow measurement.

Lake Merced - Figure III-7

This outfall serves the area east of Lake Merced to the border of the sewerage district.

A 10 ft x 11 ft-3 inch outfall line passes through the hills of Ft. Funston and discharges on the beach at the foot of the cliffs about 100 ft. from the surf line. The outfall was not well suited for a detailed investigation for the following reasons:

1. The point of discharge is extremely inaccessible.

2. During heavy storms, the breakers reach to the base of the cliffs and this would jeopardize the safety of a sampling crew.

3. In order to establish the total flow from the watershed, multiple sampling points would be required.

Vicente Street - Figure III-7

In addition to the East Lake Merced area described above, the trunk sewer at the Vicente Street diversion structure serves roughly the area bounded by Santiago Street on the north, Mt. Davidson on the east, and Lake Merced on the south.

The diversion structure is located at 45th Avenue and Vicente, and consists of an 18-inch side flow weir on the outside of a 90° bend in the 3 ft-3 inch trunk sewer.

The outfall terminates in a rectangular structure with tide gates and bar racks. Discharge is onto the beach about 75 ft. from the surf. It was believed that the hydraulic separation of suspended material in the diversion structure would preclude the use of this system for detailed analysis. In addition, the upstream diversions in the East Lake Merced area prevent an accurate description of the contributing discharges. This outfall structure is also in the surf zone during stormy weather and high tides.

Lincoln Way - Figure III-8

The diversion structures on Lincoln Way are located at the focal point of all dry weather flows originating in the Sunset District, that is south of Golden Gate Park to the city boundary and west of Twin Peaks.

At Lincoln and 39th Avenue the flow is split from an older 7 ft x 9 ft - 3 inch basket handle sewer into two 6 ft -6 inch conduits. These two mains are then connected by a 45-inch line at the junction of the 43rd Avenue trunk. The two then flow independently into the diversion structure at 48th and Lincoln Way.

The diversion structure consists of a leaping weir in which the dry weather flow drops into an 8 ft -6 inch conduit leading to the treatment plant in Golden Gate Park. Storm flows, principally from the Lincoln Way sewers, pass out of the diversion structure and discharge through a 3 compartment sewer which spills through an outlet structure on the beach.

The complexity of the flows and diversions in this system ruled out the possibility of reasonably ascertaining the origin of discharges taking place on the beach. Sampling would be additionally complicated and dangerous at the point of discharge because the structure is in the surf zone at mean sea level. During storms the waves wash across the top of the outlet structure.

Mile Rock - Not photographed

The Mile Rock outfall normally carries the effluent from the Richmond-Sunset Treatment Plant to the disposal point off the northwestern tip of the City. During wet weather, the runoff from the western half of the Richmond district is transported via this conduit. The terminous of the outfall is inaccessible.

Seacliff - Not photographed

The diversion structure is at 24th Avenue and Lake Street. Dry weather flow moves west on Lake originating in the area north of Golden Gate Park and east to the sewerage District boundary. It is picked up at the diversion structure and transported to the Richmond-Sunset Sewage Treatment Plant via a 4 ft x 6 ft -6 inch tunnel.

The outfall could not be seen from China Beach because it is located in the rocky cliffs which extend from there to Sutro Heights. This and the fact that there are two storm flow diversions upstream made the location unsuitable as a monitoring point.

Baker's Beach - Figure III-8

The Baker's Beach outlet structure is the terminous of storm water over-flows from two points: 22nd Avenue and Lake Street, and 17th Avenue and Lake Street. Runoff originates in the Richmond District, principally east of 19th Avenue.

The overflow lines drop about 100 feet through an average distance of about 2,000 feet to the beach where they join. The flow continues for an additional 450 feet to the outfall structure which is located about 75 feet from the mean surf line.

This outfall would have been a suitable point for an additional monitoring station. The upstream watershed principally is residential and could provide meaningful information on areas of this type. Preliminary considerations show that the trunk sewer at 22nd Avenue and Lake Street could have been safely plugged, allowing the dry weather flow to pass through a suitable orifice. During periods of significant runoff only a small fraction of the flow would have continued down the trunk sewer, while the majority would have discharged through the outfall structure. This would have eliminated the necessity of dual sampling stations, which would otherwise be required for separate sampling of each flow stream.

The major drawback to the use of this system is the high velocities which result from the steep hydraulic gradient of the outfall system. Specialized apparatus would have been required for sampling and flow monitoring.

Pierce and Laguna Streets - Figure III-9 and Figure III-10 (The Marina Area)

The pumping station at the foot of Pierce Street receives the dry weather flow from the entire northwest corner of the North Point Sewerage District. This area is bounded roughly by Washington Street on the south and Leavenworth Street on the east. The flow is pumped directly from the foot of Pierce Street to the North Point Treatment Plant.

During storms, the runoff from the eastern sector of this drainage area is discharged at the foot of Laguna Street through a 6 ft circular conduit. Dry weather interception is effected by diversion weirs and interceptor sewers placed below the larger storm flow line. There are three of these structures. Their location and size are tabulated below:

Location	Size of D.W. Interceptor
Chestnut and Laguna	15 inches
North Point and Laguna	21 inches
Beach and Laguna	12 inches

The remainder of the storm water from the entire area, except for a small amount diverted at Baker Street, discharges through the 7 ft. outfall below the Marina Pumping Plant. This latter outfall is submerged at high tide.

The multiplicity of diversion points on the Laguna Street sewer tended to rule out further study on this outfall. Dry weather flow patterns normally could have been established only with difficulty. However, the city modified the diversion structures to permit a detailed investigation of this sector.

The submerged outlet, as well as the Baker Street Diversion, would have seriously inhibited a detailed investigation of the Marina outfall.

Beach Street - Not photographed

This outfall is located just ahead of the North Point Sewage Treatment Plant on the trunk sewer which serves the area east of that discharging to the Marina, west of Telegraph Hill, and north of Broadway. Discharge takes place at a point between Pier 37 and Pier 39.

Jackson Street - Not photographed

The Jackson Street diversion provides the greatest storm water relief for the North Point main. The diversion structure is located at Jackson and Sansome Streets. The point of discharge is between Piers 1 and 3, but it like others is submerged.

Seventh Street, China Basin - Figure III-

This structure discharges storm water from nearly the entire industrial park area. However during dry weather, sewage is intercepted at several points upstream. Flow patterns in the upstream system are quite complex, and the dry weather flow and waste characteristics of the contributing watershed could be established only with a multiplicity of sample points.

The outlet structure is one of the largest in the sewage system. The sewer itself is a four compartment box structure with each compartment measuring 10 ft. x 7 ft-6 inches. The interceptor trench is at an elevation generally below the level of the water in China Basin; consequently tide gates have been installed to prevent backflow.

Marin Street, Islais Creek - Figure III-9

The area from the boundary of the North Point District south to Islais Creek is served by one trunk sewer, which converges with another coming from the west at the Marin Street diversion. The dry weather flow then passes to the Selby Street structure on the south side of the creek.

During storm runoff most of the flow from the north bypasses into Islais Creek at the Third Street Bridge. The principal discharge at Marin Street therefore originates in the area to the west.

There are no upstream diversions on the latter, and the structure could conceivably have been used as a sampling station. However the structure is the smaller of two at the head of Islais Creek, and the other (Selby Street) is more suitable for this reason.

Selby Street, Islais Creek - Figure III-12

The entire dry and wet weather flow from the western half of the Southeast Sewerage District flows to the Selby Street diversion structure. Dry weather flow is intercepted at that point by the trunk from the Marin Street diversion and flows back to the Southeast Sewage Treatment Plant. Storm flow is mixed with the small flow from the north and the majority spills into Islais Creek through the outfall structure, while a small amount continues toward the treatment plant.

This site provided an excellent location for a sampling station for the following reasons:

1. The drainage area is relatively large, yet is well defined.

2. A portion of the flow comes from industrial areas.

3. With minor modifications to the outlet structure the flow was segregated from that originating in other areas.

4. Dry weather flow patterns could be established with relative ease.

Yosemite Street, South Basin - Figure III-13

Except for the Sunnydale Avenue overflow described below, this is the only bypass structure for storm waters originating in the southern and middle sections of the Southeast Sewerage District. A pumping station located at Yosemite Avenue and Ingalls Street picks up the dry weather flow, which passes through the Hunter's Point tunnel to the Southeast Sewage Treatment Plant.

Storm flow discharges into a channel through parallel conduits (9 ft x 7 ft -3 inches and 11 ft -6 inches x 6 ft -6 inches). However, the outlets were silted up to about mid-depth on a level with the existing channel, and it was doubtful whether the outfall could discharge the indicated flow.

The upstream diversion channel depth made this location unsuitable for further study.

Sunnydale Avenue - Figure III-13

This structure provides a bypass for storm waters originating southwest of Candlestick Park. It consists of a regular box culvert with a single tide gate. The structure was, at the time of the survey, boarded up, preventing discharge from occurring except under extreme flows.

DESCRIPTION OF PILOT AREAS

A previous section contained the results of a preliminary survey of the 15 major storm water overflow systems in San Francisco. Each of the systems was evaluated on the basis of previously mentioned criteria, and two were selected as the most suitable for the study. The two systems, designated Selby Street (#13) and Laguna Street (#8) because of the location of the outfalls, are described in more detail in this section.

The Selby Street system was selected as the primary pilot sector because of its large size and the fact that the outfall structure is well suited for estimation of flows. However, receiving water studies could not be carried out at the Selby Street outfall because at the time of the studies, the Southeast Sewage Treatment Plant discharged its effluent in close proximity to the Selby Street outfall structure on Islais Creek. This fact coupled with the discharge from other outfalls on Islais Creek would have made it difficult to distinguish between the effects of each discharge. The Laguna Street system was selected as the secondary storm flow monitoring system and it was the only system in which receiving water studies were conducted. The Laguna Street outfall discharges into the easterly sector of the municipal marina which was judged to be most suitable for establishing cause and effect relationships of combined sewer overflows.

Selby Street System

The Selby Street pilot area (shown in Figure III-14) comprises roughly 48 percent of the Southeast Sewerage District. It consists of approximately

3,400 acres of land, and ranges in elevation from about 600 ft on the southeastern slope of Twin Peaks to near sea level. The natural drainage trough followed by the principal trunk sewer extends a distance of nearly four miles from an elevation of about 300 ft near the southern city limit to sea level at the outfall structure.

Land use in the pilot area is extremely varied. The breakdown into the four basic use classifications is six percent industrial, two percent commercial, 77 percent residential, and 15 percent vacant land. The population of the Selby Street sector is estimated to be 81,000, based on 1960 census figures. Thus the population density is about 24 persons per acre.

The entire dry and wet weather flow from this area converges at the Selby Street diversion-outfall structure. Dry weather flow is intercepted at the structure (Figure III-15) and carried to the Southeast Sewage Treatment Plant. During stormflow periods the runoff-sewage mixture spills directly into Islais Creek. Only a relatively small amount is diverted to the treatment plant because the hydraulic capacity of the plant is limited to the equivalent of the runoff from 0.02 inches of rainfall per hour.

The main trunk sewer serving the pilot area is about 22,500 ft in length and varies from a normal conduit three feet in diameter to a 7 ft-6 inch by 30 ft, three compartment box structure above the outfall. Sewer grades in the trunk vary from a maximum of 3.1 percent in the upper reaches to 0.11 percent in the three compartment section. The lateral sewer system is of conventional design and consists of approximately 130 miles of conduit ranging in size down to six inches in diameter.

Laguna Street System

The Laguna Street outfall drains an area of approximately 370 acres lying south of the waterfront (Figure III-14). The drainage area rises to an elevation of about 300 ft near Nob Hill, and consequently the 8,600 ft trunk sewer contains some relatively steep grades.

The area is almost entirely residential. Figures III-2 through III-4 show that land used for commerce and industry, along with vacant land, amounts to less than 10 percent of the area. The residential use is for the most part, restricted to apartments. There is very little vegetation in the area.

The population density of this sector is much greater than that of the Selby Street sector. With an estimated population of 25,000 there are approximately 68 persons per acre.

The trunk sewer, shown in Figure III-14, begins in the southeast corner of the sector and lies diagonally across it, terminating in a six foot circular conduit at the foot of Laguna Street. There are three points of dry weather diversion on Laguna Street which carry the sewage ultimately to the Marina Pumping Station. From there the flow is pumped directly to the North Point Sewage Treatment Plant.

As previously mentioned, the sewer grades are steep; the majority fall in the range of one to three percent. There are about 15 miles of laterals, most of which are between eight and 24 inches in diameter.

For the duration of the study, the diversion of Chestnut Street was blocked, forcing the North Point Street diversion to intercept most of the flow. This modification made it possible to sample at a single point the dry weather flow from the entire area. Discharges below North Point Street are minor, hence the last diversion on Beach Street intercepts very little flow.

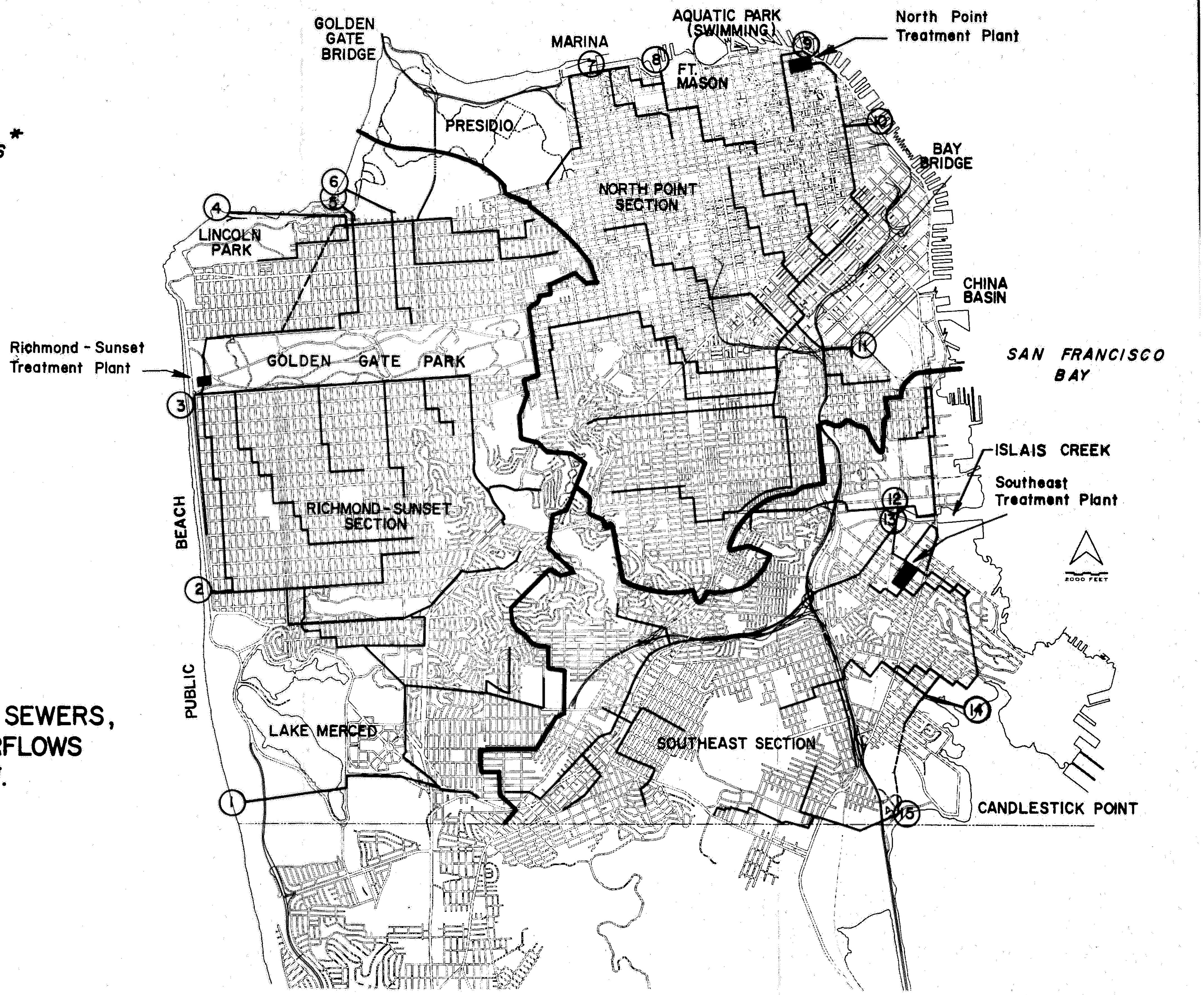
During storm runoff periods, only a small percentage of the flow is diverted, and the majority passes through the outfall at the foot of Laguna Street.

PACIFIC OCEAN

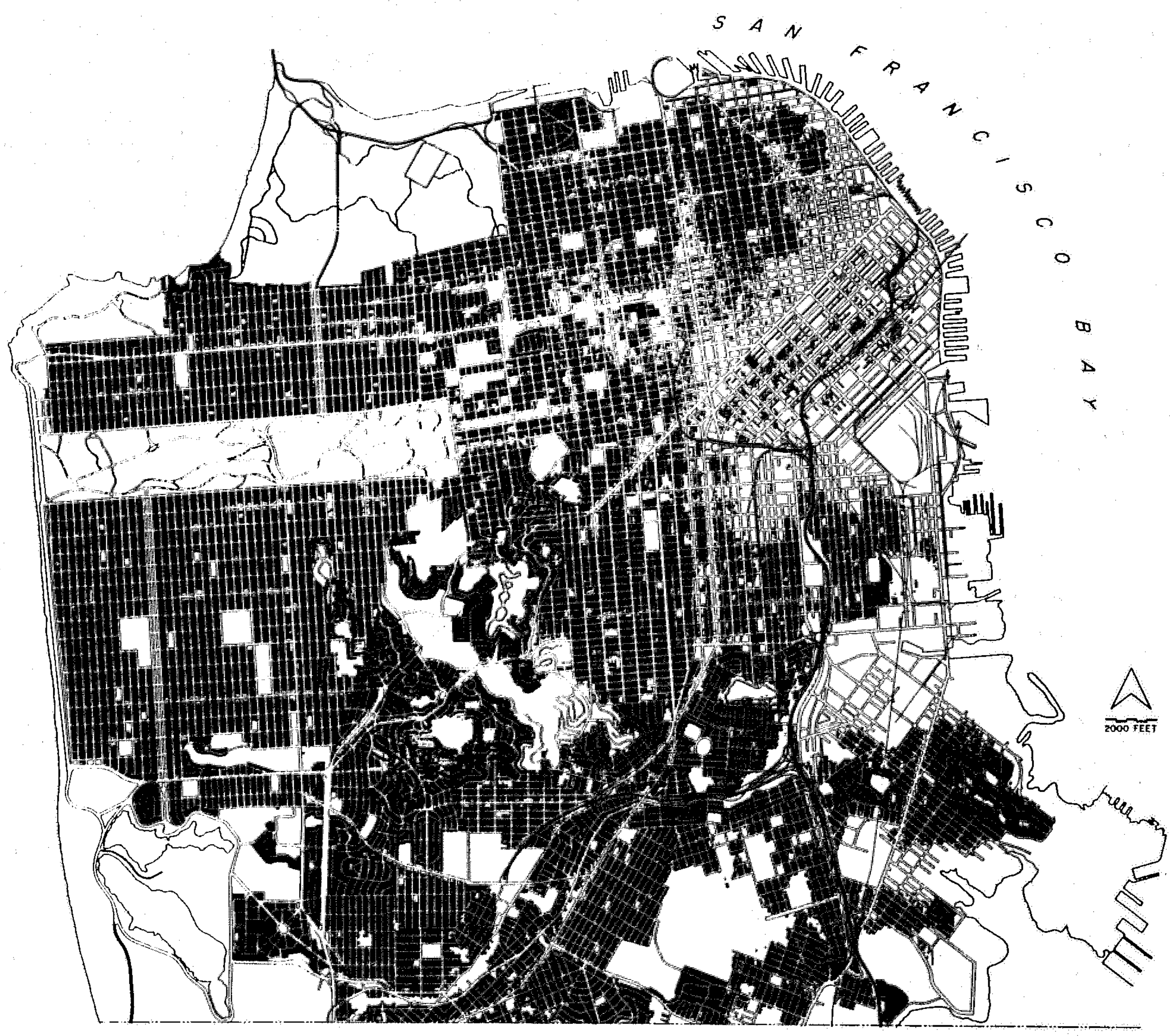
*MAJOR OVERFLOWS, CFS**

1	LAKE MERCED	960
2	VICENTE ST.	1000
3	LINCOLN WAY	1800
4	MILE ROCK	1145
5	SEA CLIFF	520
6	BAKERS BEACH	1200
7	PIERCE ST.	460
8	LAGUNA ST.	512
9	BEACH ST.	550
10	JACKSON ST.	600
11	SEVENTH ST.	2700
12	MARIN ST.	1175
13	SELBY ST.	1800
14	YOSEMITE ST.	1170
15	SUNNYDALE AVE.	600

* *Figures indicate approx. discharge for 5-year critical storm.*



SEWERAGE DISTRICTS, TRUNK SEWERS, AND MAJOR STORMWATER OVERFLOWS SAN FRANCISCO, CALIF.



LAND USED FOR RESIDENCE

SOURCE 1961 - 64 LAND USE SURVEY

PREPARED BY THE SAN FRANCISCO DEPARTMENT OF CITY PLANNING 1964

LAND USED FOR COMMERCE

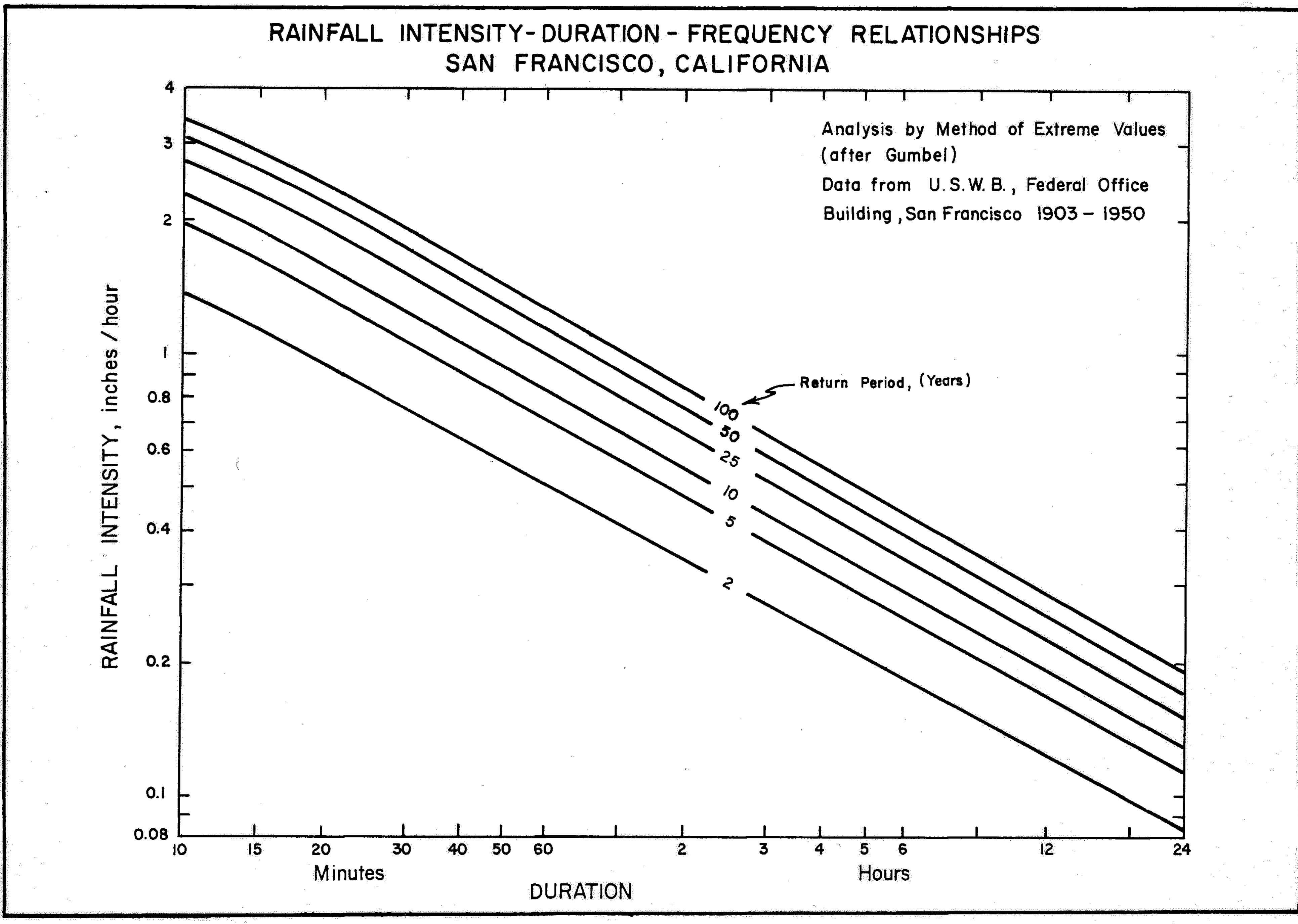
SOURCE: 1961 - 64 LAND USE SURVEY

PREPARED BY THE SAN FRANCISCO DEPARTMENT OF CITY PLANNING · 1964

LAND USED FOR INDUSTRY

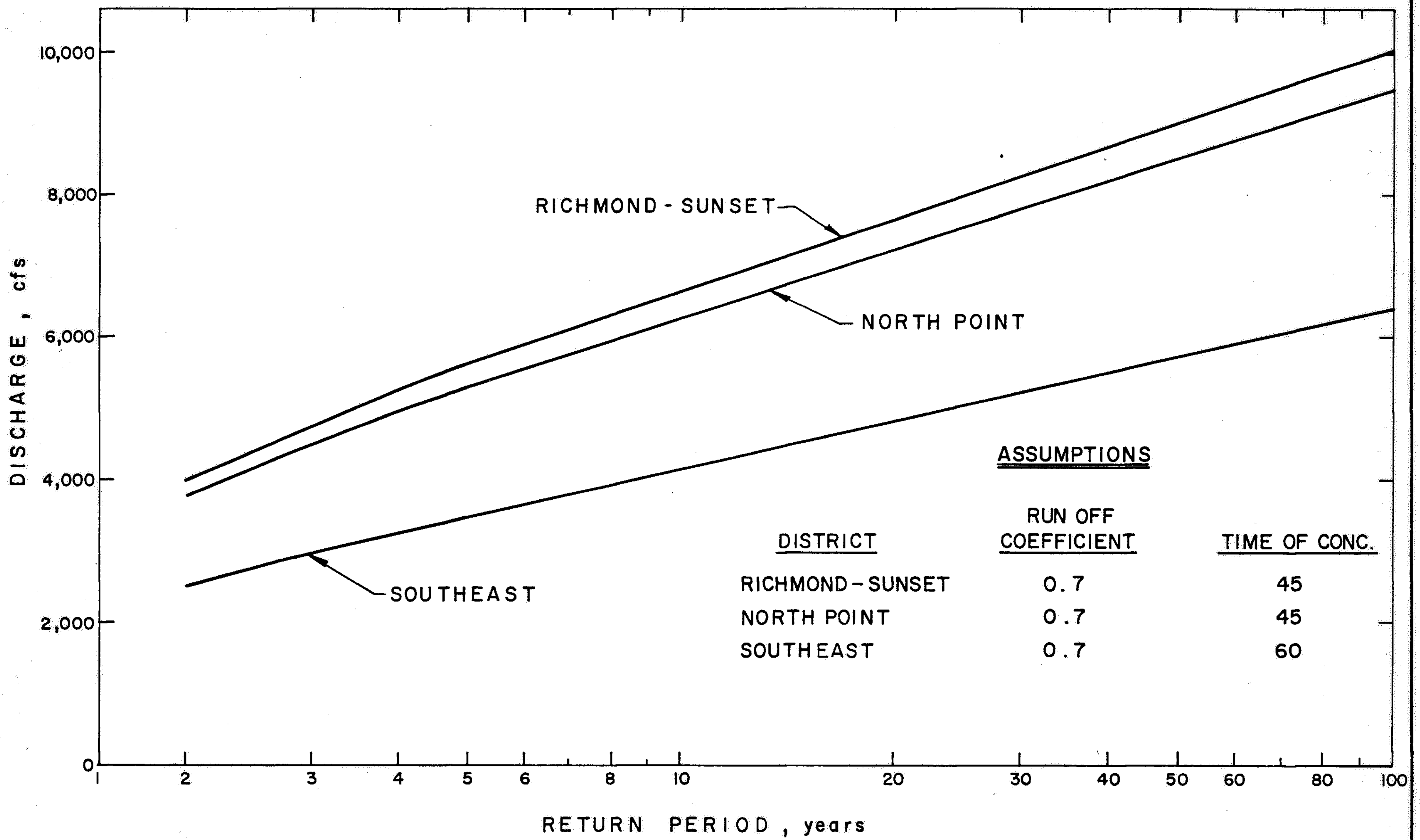
SOURCE: 1961 - 64 LAND USE SURVEY

PREPARED BY THE SAN FRANCISCO DEPARTMENT OF CITY PLANNING 1964



ENGINEERING-SCIENCE, INC.

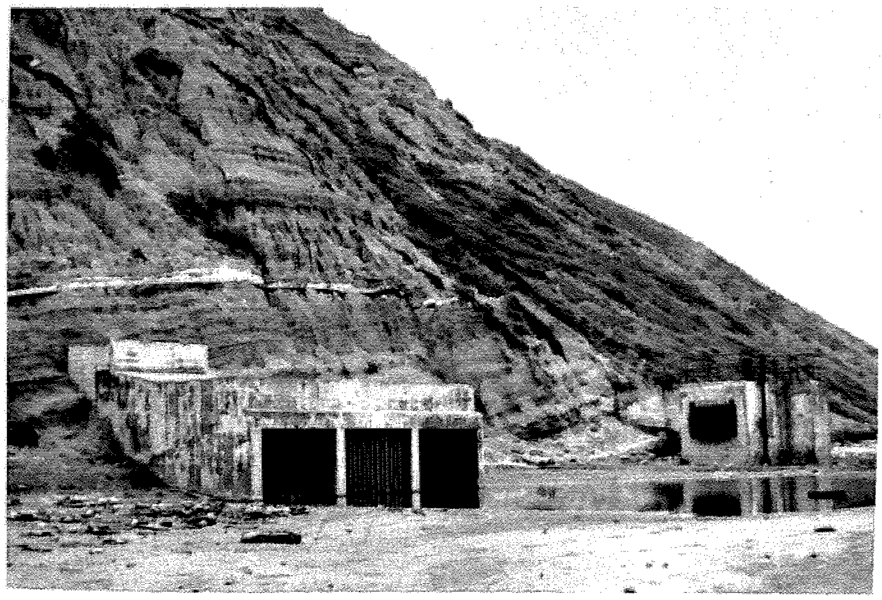
FIGURE III - 5



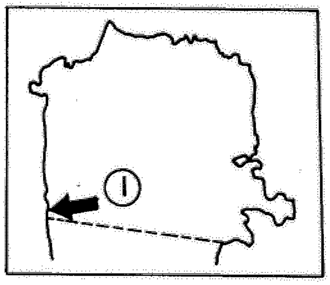
ESTIMATED STORM WATER DISCHARGE – RETURN PERIOD RELATIONSHIPS
SAN FRANCISCO, CALIFORNIA

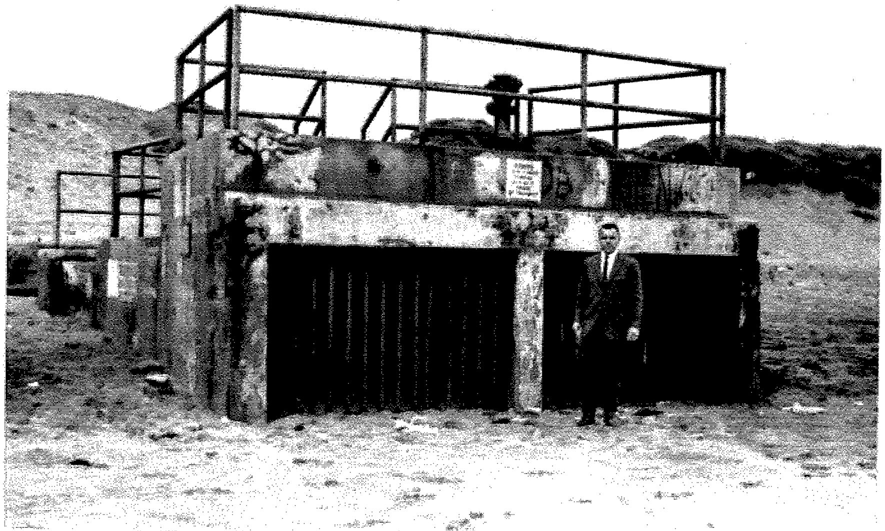
ENGINEERING - SCIENCE, INC.

FIGURE III - 6

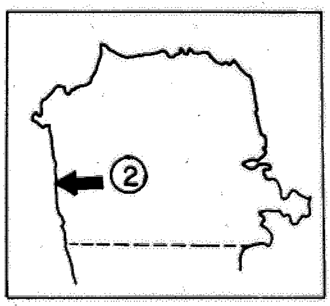


LAKE MERCED

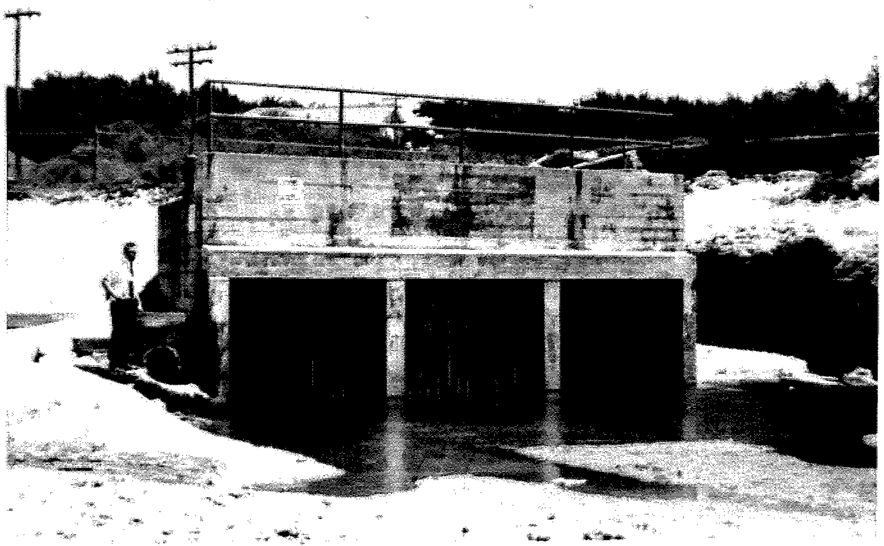




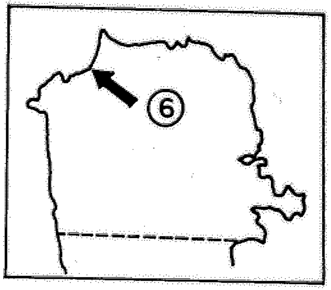
VICENTE ST.

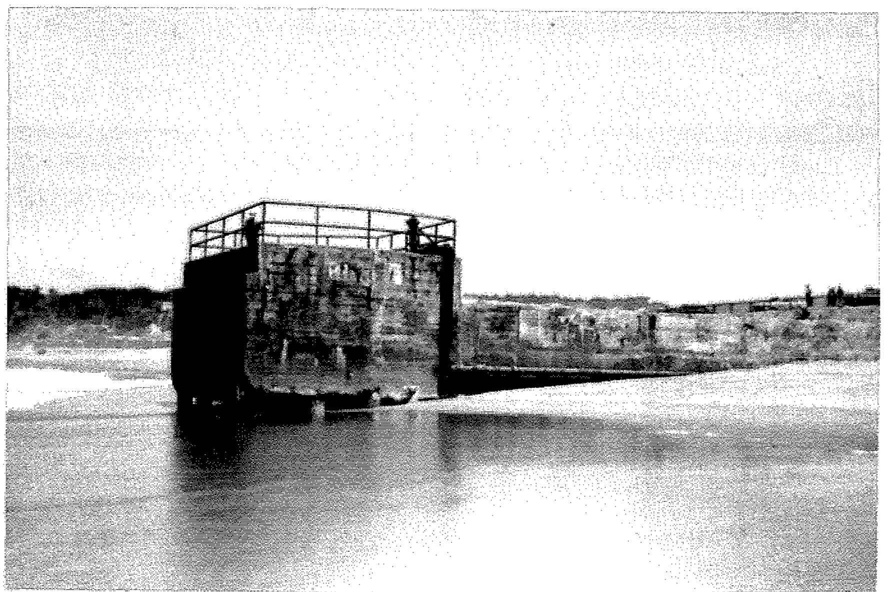


COMBINED SEWER OVERFLOW OUTFALL STRUCTURES, SAN FRANCISCO

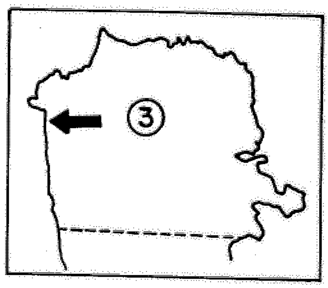


BAKERS BEACH

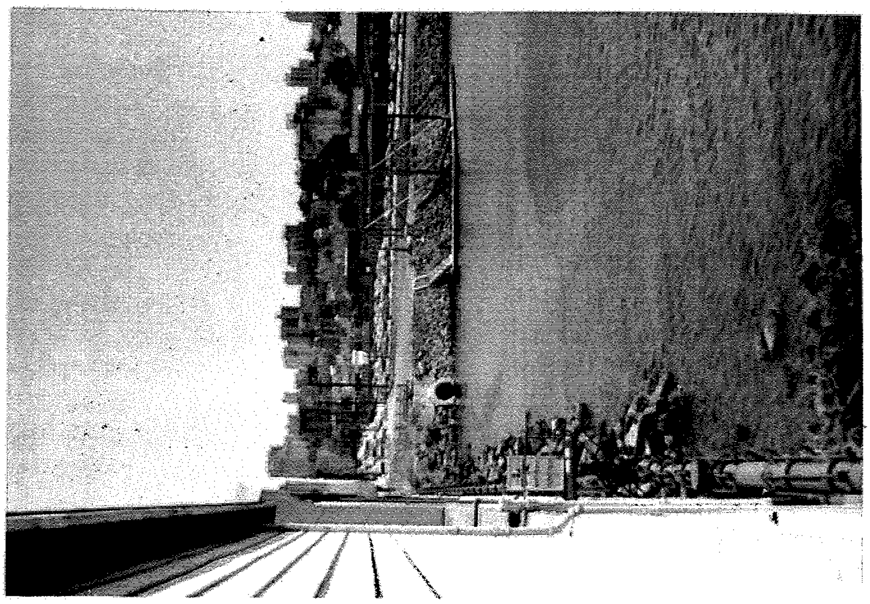




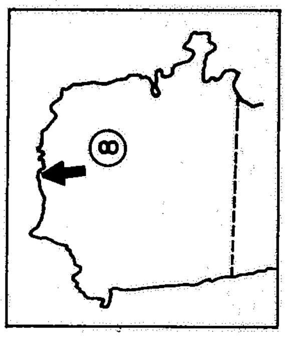
LINCOLN WAY



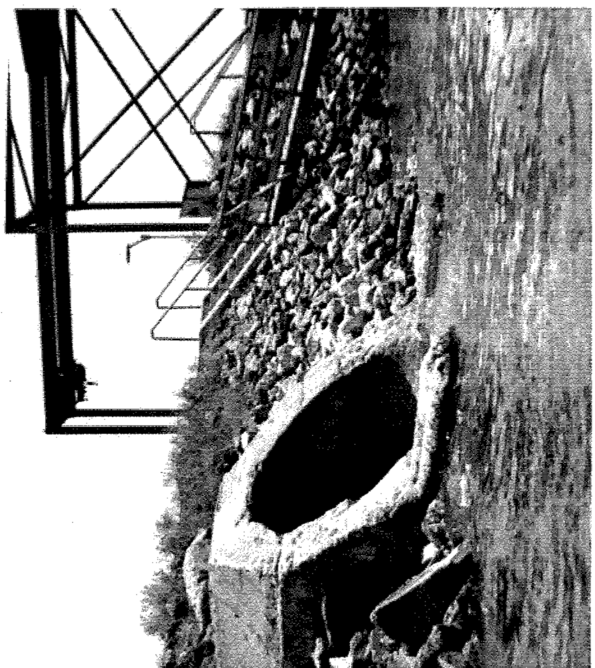
COMBINED SEWER OVERFLOW OUTFALL STRUCTURES, SAN FRANCISCO

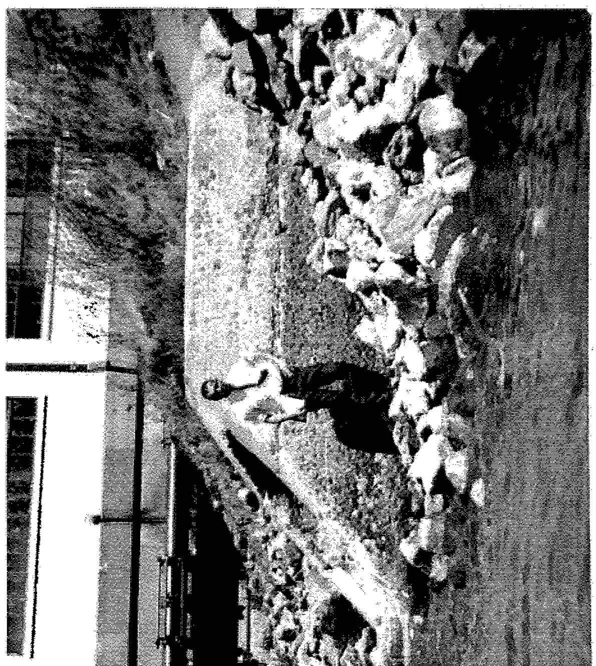


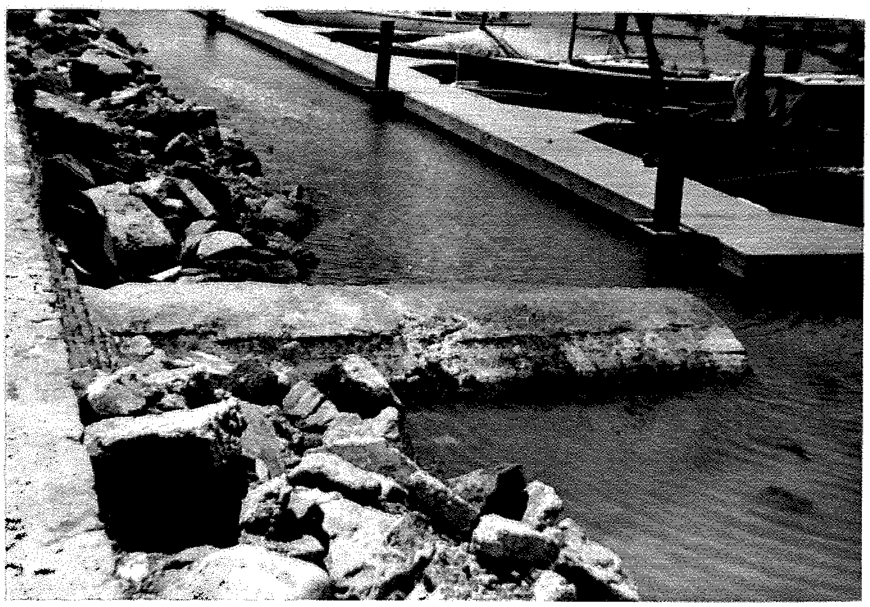
LAGUNA ST.

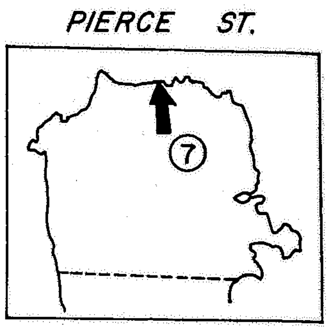


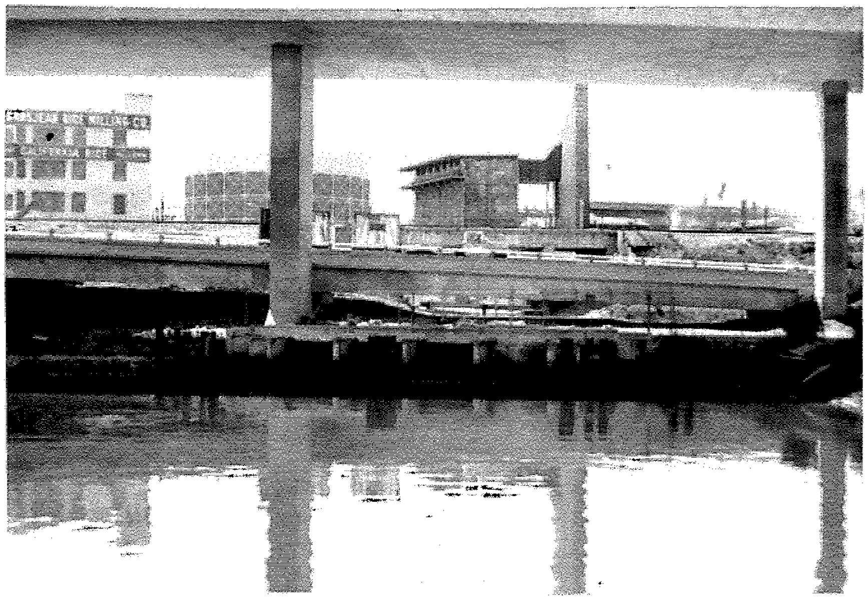
COMBINED SEWER OVERFLOW OUTFALL STRUCTURES, SAN FRANCISCO

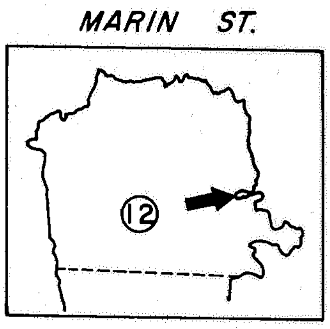






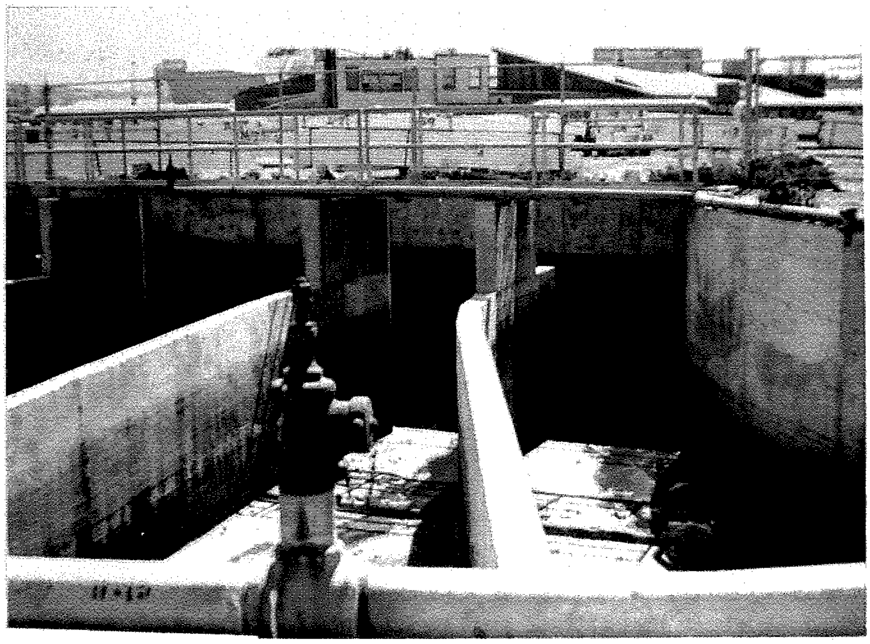


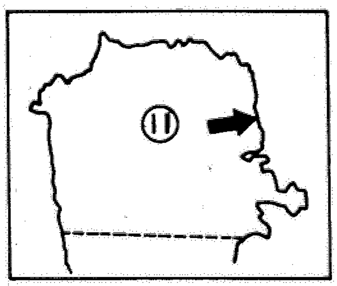




COMBINED SEWER OVERFLOW OUTFALL STRUCTURES, SAN FRANCISCO

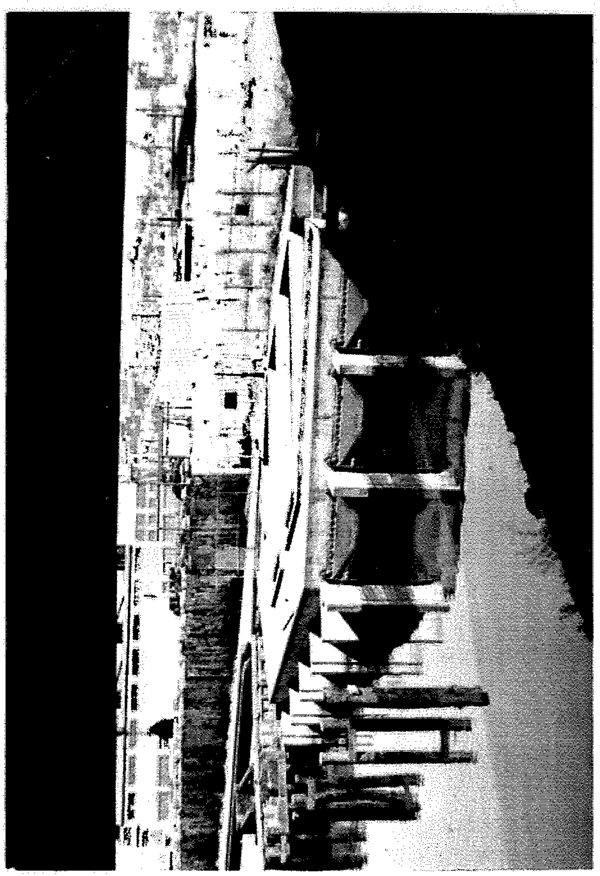
FIGURE III - 11

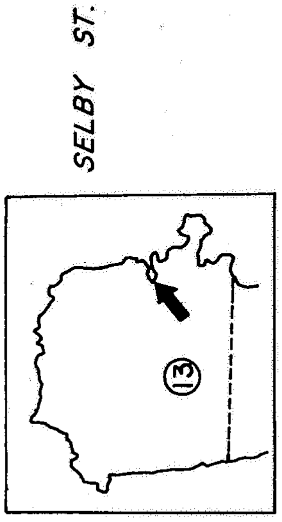


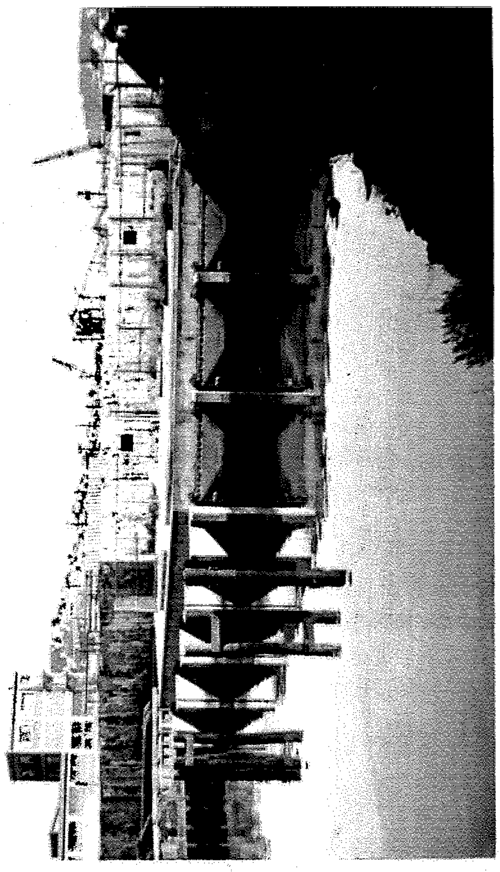


SEVENTH ST.

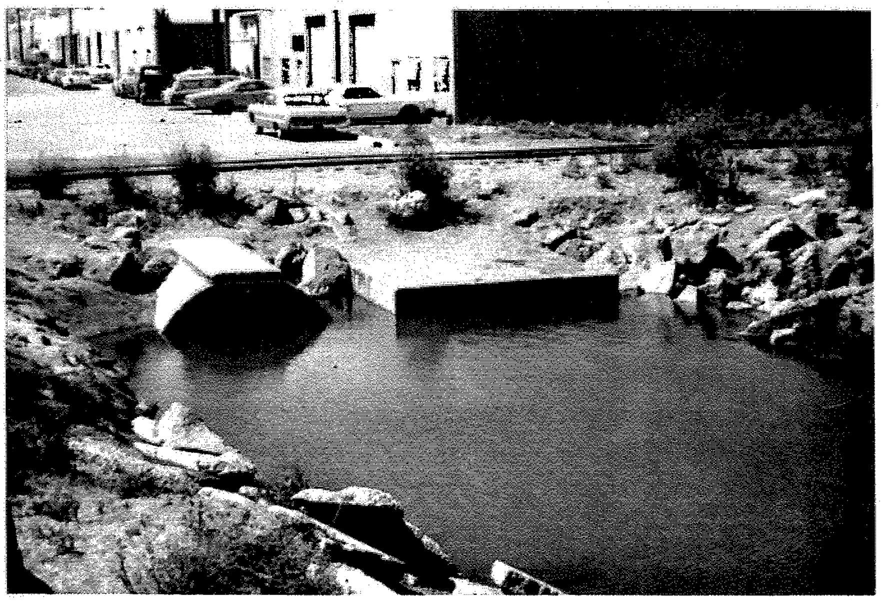
COMBINED SEWER OVERFLOW OUTFALL STRUCTURES, SAN FRANCISCO

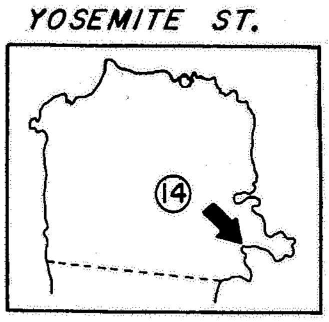


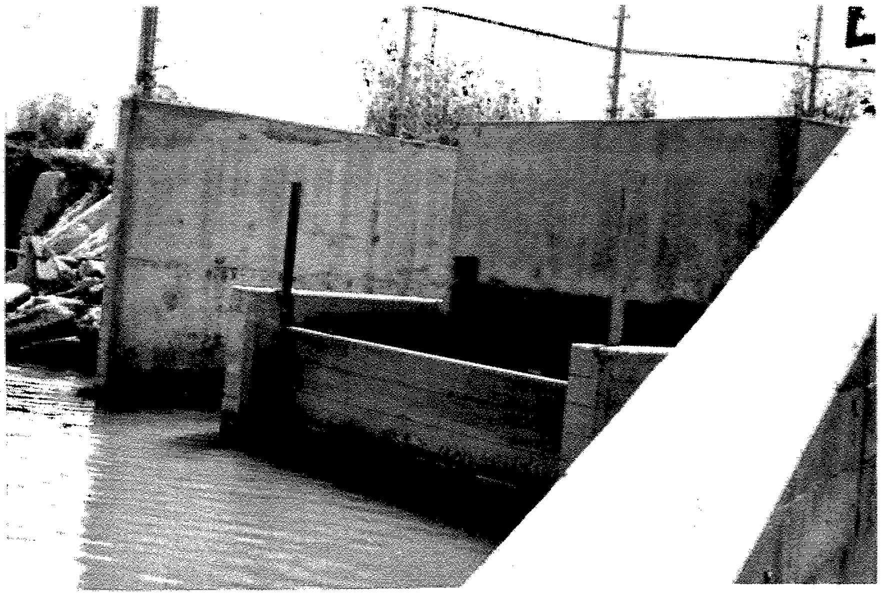


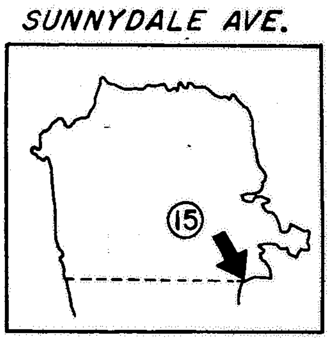


COMBINED SEWER OVERFLOW OUTFALL STRUCTURES, SAN FRANCISCO









COMBINED SEWER OVERFLOW OUTFALL STRUCTURES, SAN FRANCISCO

FIGURE III- 14

SAN FRANCISCO
COMBINED SEWER
OVERFLOW STUDY

PILOT AREAS

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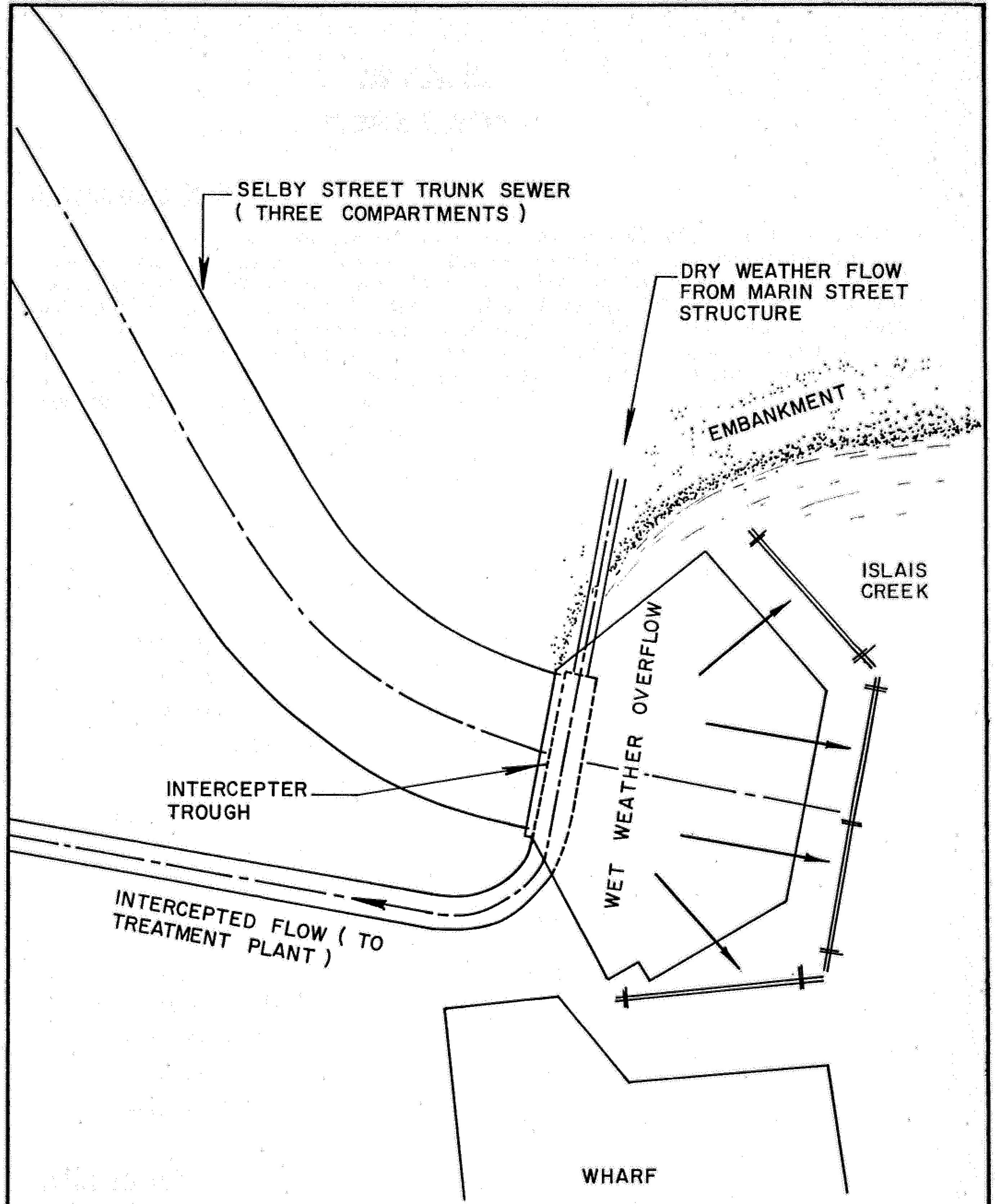


FLOW PATTERNS AT SELBY STREET
OVERFLOW STRUCTURE

CHAPTER IV

METHODS OF STUDY

DRY WEATHER MONITORING

Dry weather monitoring was conducted in both pilot areas in order to investigate the general effects of the dry weather waste streams on the characteristics of wet weather discharges, and to provide data for the calculation of the mass contributions of normal sewage flow to the wet weather overflows. Dry weather monitoring was conducted for eight days in the Selby Street System and for six days in the Laguna Street System, as shown in Table IV-1. Coliform monitoring was conducted on two separate days in each system. These are also shown in Table IV-1.

TABLE IV-1

DATES OF DRY WEATHER MONITORING

Date	Pilot Area(s) Monitored
6 September 1966	Selby, Laguna
8-9 September 1966	Selby, Laguna
11-12 September 1966	Selby, Laguna
17-18 September 1966	Selby, Laguna
20-21 September 1966	Selby, Laguna
23-24 September 1966	Selby, Laguna
26-27 September 1966	Selby
2-3 October 1966	Selby

DATES OF DRY WEATHER COLIFORM MONITORING

Date	Pilot Area
20 December 1966	Laguna
17 January 1967	
13 June 1967	Selby
1 August 1967	

Selby Street

Flow Measurement: An integral part of the dry weather monitoring was the determination of flows in the trunk sewer, which consists of three parallel channels up to the point of confluence with the flow from north of Islais Creek (the Marin Street sewer). Without modification of the flow pattern it would have been necessary to monitor the three streams independently, which would have substantially increased the work load.

In order to obtain a single stream it was necessary to block the two outside compartments with sandbag dikes at a point about 150 ft above the outfall structure as shown in Figure IV-1. At this location there are inter-compartment windows with sills one foot above the normal channel invert. This caused ponding of the flow upstream. However, there were about six inches of sediment in the channels from prior deposition, and the average depth of flow was only increased about 150 percent in making this modification.

Most conventional flow measuring techniques require the establishment of a critical flow section which often includes the creation of an upstream pond. It was decided that such ponding should be kept to a minimum in order to prevent additional deposition of suspended solids which would give a false picture of the normal sewage quality characteristics. A technique, the tracer dilution method, which does not require any interference with the flowing stream was chosen. A suitable tracer was introduced at constant rate at an upstream point and samples were taken further downstream after adequate mixing. This method has the advantage of providing flows directly, and thus velocity considerations are not required.

The tracer used was Pontacyl Brilliant Pink B flourescent dye, which has the following advantages:

1. Only small quantities of dye are required because precise determination of the dye concentration is possible at concentrations of 10^{-3} mg/1. Thus cost and quantity restrictions were reduced.

2. In most sewage flows the "background" of this particular dye is not significant. The amount of tracer does not have to be materially increased in order to eliminate spurious background effects.

3. The tracer is not significantly affected by the presence of materials normally found in sewage.

The points of tracer injection and sample collection are also shown in Figure IV-1. Quantitative analyses for the tracer were made with a Turner Model 110 Fluorometer.

The tracer dilution technique was employed during the initial phases of the dry weather program, but had to be discontinued because of technical difficulties. One of the problems involved was injection of the dye. During low flow periods, sludge banks were exposed below the injection manhole, and uneven distribution of the tracer resulted. When this situation was corrected it was found that insufficient turbulence existed for mixing purposes in the short section above the outfall structure. To offset this condition a partial dam was constructed across the channel above the sampling point. This caused an elevated backwater condition and a turbulent section downstream.

As a result of these difficulties only limited reliable data were gathered by the tracer dilution method, therefore, after the completion of the dry weather sampling, it was decided to obtain a more detailed description of the flows, using another method. A Palmer-Bowlus flume with a 4 ft. throat and 6 inch invert slab was constructed from 16 gauge galvanized sheet metal. This was installed just below the sampling station as shown in Figure IV-1; it was held in place with sandbag side supports. A stilling well was also constructed with sandbags directly below the sampling station manhole. A continuous record of the upstream water level was made possible by mounting a Stevens Water Level Recorder on the manhole cover support and extending a line with a float down to the stilling well. Continuous water level readings were obtained during a one-week period. The calibration curve is shown in Figure IV-2. (Note that the flow-gauge height relationship is nearly linear in the range of interest and proportionality constant is approximately 12.5 mgd per ft of gauge height). The theoretical calibration closely agrees with the data obtained with the tracer dilution technique. Because of the mixing in the tail water of the flume, dispersion of the dye was quite satisfactory.

Sampling: Dry weather sampling was conducted at a station about 100 ft below the point of converging flow, as shown in Figure IV-1. Grab samples were taken at three hour intervals for 24 hours during each sampling period. The temperature of the sample was immediately obtained. The samples were preserved by adding mercuric chloride to a concentration of 10 mg/l. The samples for BOD determinations, however, were not treated with mercuric chloride, but were refrigerated at the laboratory facility of the Southeast Sewage Treatment Plant.

Upon arriving at the laboratory, the sampling crew placed a high speed mixer in the sampling container. During mixing, aliquots were removed from a spigot near the bottom of the bucket, and fractions were set aside for the various analyses. Immediate analyses consisted of pH and conductivity. The fluorescent tracer determinations were also made at this time.

Separate portions for various tests were taken as follows:

Portion	Volume
Floatables	3 liters
Grease	1 liter
General chemical	2 liters
BOD	1 liter (refrigerated)

Within 12 hours of sampling the containers were transported to the laboratory where they were maintained at refrigeration temperatures.

During the dry weather coliform monitoring, dilution of the sewage samples and inoculation of the tubes were carried out in the field laboratory at the outfall structure. Immediately after inoculation the tubes were placed in a 35^{o} C incubator in the field laboratory. The tubes were later transferred to an incubator in the main laboratory.

Laguna Street

The Laguna Street System, shown in Figure IV-3, served as the secondary pilot sector for this study. Consequently, sampling at this location was carried out on a reduced scale.

Flow Measurement: Because of adequate mixing below the point of dye injection, the tracer dilution method gave consistent results at Laguna Street and no other method was used for the flow determinations.

Sampling: The sampling procedure employed at Laguna Street was identical to that at Selby Street. The designated monitoring station is shown in Figure IV-3.

WET WEATHER MONITORING

Selby Street

Figures IV-4 and IV-5 show a plan and section respectively of the Selby Street Diversion Structure. Included in the plan drawing are locations of monitoring and sampling operations.

The presence of the interceptor trough in the Selby Street overflow structure posed somewhat of a problem for the wet weather monitoring program, because of the possibility of a significant flow from the Marin Street structure. The time of concentration of the Marin Street sector is much less than that of the Selby Street sector, and as a consequence the Marin Street structure fills more rapidly, causing a substantial flow to divert to Selby Street via the interjacent trunk sewer. For reliable wet weather data to be obtained, it was essential that the mixing of the two streams be prevented.

To accomplish this, a cover was placed over the interceptor trough, and a steel bulkhead was fixed over the remaining exposed section of the sewer from Marin Street, and at the downstream end of the trough a butterfly gate was installed across the aperture remaining above the trough cover. The structural modifications are shown in Figure IV-6. During dry weather conditions the gate was fixed in an open position, allowing the flow from the Selby Street sewer to enter the interceptor stream. However, under storm conditions the gate was closed, separating the two streams. Under these circumstances, all flow from the Selby Street sewer passed through the overflow structure.

Flow Measurement: Several methods were utilized for the measurement of storm flow in the Selby Street outfall structure.

1. Velocity determinations at a point 50 ft above the outfall structure with current meters.

2. Differential head measurements over the broad-crested weirs of the outfall structure.

3. Measurement of surface velocities in the outfall structure.

4. Measurement of vertical velocity profiles in the outfall structure with a portable current meter.

The current meters in the sewer did not yield reliable data because they were immediately fouled with rags and other debris. It was anticipated that the tide gates in the outfall structure would exert a significant effect upon the discharge from the outfall structure, and the theoretical head-discharge relationship for a broad crested weir of similar shape was used for comparison purposes only.

Surface velocities in the outfall structure were measured by timing the traverse of styrofoam drogues across a measured control section. The surface velocity values were converted to average velocities using a factor of 0.64, which accounts for horizontal and vertical velocity distributions (0.8 correction factor for each axis). Discharge values were obtained by multiplying the average cross-sectional area of the control section by the computed average velocity.

The portable current meter method was used to establish discharge values under low head conditions and also to check the results of the surface velocity determinations. The current meter was adapted from a boat speed sensor unit, which had a streamlined shape, and the unit was fitted with a large propeller to provide for low velocity sensitivity. A picture of the meter is shown in Figure IV-7. For these measurements a second control section was established nearer to the tide gates, where the maximum velocities occurred. Under four separate head conditions vertical velocity profiles were established at one location (Figure IV-4), which was midway between two super-structure support pillars. Mean velocities for the monitoring point were determined, and these were multiplied by a factor of 0.8 (to account for the horizontal velocity profile induced by the support pillars) to obtain the average velocities in the control section. Discharge values were computed by multiplying the average velocity by the cross-sectional area of the control section.

Water elevations in the outfall structure and in the receiving water, Islais Creek, were continuously measured by the bubbler tube technique. In this method, a small amount of air (in this case bottled nitrogen) is bled through a pipe, into the liquid. The air pressure required to displace the liquid in the pipe is proportional to the liquid head above the pipe opening. A pressure gauge, calibrated in terms of depth, measures the bleed air pressure and records the depth on a chart.

Outfall structure water levels were used throughout the study for purposes of estimating discharge rates. The rating curve, Figure IV-8, was developed from the results of the surface velocity determinations and the portable current meter measurements. The lower portions of the curve were estimated, based on the observation that discharge did not commence until the water level reached a height of 0.35 ft above the tide gate sill.

In Figure IV-8 a comparison is made with a theoretical discharge curve for broad crested weirs of similar shape ($Q = CLH^{3/2}$). The weir coefficient was assumed to be 3.2 (14) and the total weir length was 80 ft. As anticipated, the calculated discharge was less than that predicted by the theoretical curve (approximately 10 percent less), and it is assumed that the major reason was the influence of the tide gates.

Sampling: Wet weather sampling was carried out with specially designed samplers installed in the outfall structure. In order to secure representative samples, one sampler was located in each of the three principal flow streams, as shown in Figure IV-4. A description of the samplers and their operation is included in Appendix A. The following schedule was set up as a guide for wet weather sampling, however, deviations were made according to the judgment of the sampling crews:

Time*	Sample Taken every
0-2 hours	10 minutes
2-4 hours	20 minutes
4-8 hours	30 minutes
8 hours	60 minutes

* Datum = commencement of overflow

Approximately two minutes were required to obtain a composite sample from the three samples. Equal volumes from each sampler were composited in a specially constructed 5 gal container fitted with a spigot near the bottom. The contents were thoroughly mixed by hand, and during mixing aliquots were withdrawn through the spigot. No preservative was added to the samples as they were returned to the laboratory and refrigerated within 8 hours and analyses were begun within 24 hours.

As in the dry weather monitoring, the coliform tubes were inoculated and incubated in the field laboratory.

Sampling Error: In order to estimate the errors involved in obtaining a representative sample, two samples of the overflow were taken in rapid succession during an overflow period. The analytical results from the two samples were compared, and based on the range of values for each constituent, estimates of standard errors and coefficients of variation were made. These are shown in Table IV-2. Based on this data it is concluded that a representative sample can be obtained with the samplers.

Site Installation: A prefabricated 10 ft by 10 ft steel building was erected at the monitoring site for purposes of housing the recording instruments and other apparatus and for sample preparation. In addition to the special samplers and flow metering devices, tanks of compressed nitrogen (for sample ejection and bubbler-tube operation) were located at various points within the outfall confines.

TABLE IV-2

ANALYSIS OF SAMPLING ERROR

Constituent	Mean Value x	Range	Standard Error	Coefficient of Variation
BOD	42.5 mg/1	1 mg/1	0.74 mg/1	0.017
COD	134.5 mg/1	3 mg/1	2.2 mg/1	0.016
Alkalinity	38.85 mg/1	4.9 mg/1	3.62 mg/1	0.093
Ca^{++}	10.6 mg/1	0.4 mg/1	0.296 mg/1	0.028
Mg^{++}	1.9 mg/1	0	0.03 mg/1	0.016
Cl^{-}	19.0 mg/1	1 mg/1	0.74 mg/1	0.039
Na^{+}	16.5 mg/1	3 mg/1	2.22 mg/1	0.125
K^{+}	2.075 mg/1	0.15 mg/1	0.111 mg/1	0.054
$PO_4^{\equiv}$	1.236 mg/1	0.328 mg/1	0.243 mg/1	0.197
$SO_4^{=}$	12 mg/1	4 mg/1	2.96 mg/1	0.244
Floatables	2.2 mg/1	.6 mg/1	.444 mg/1	0.202
S.S.	179 mg/1	2 mg/1	1.48 mg/1	0.084
V.S.S.	74 mg/1	20 mg/1	14.8 mg/1	0.200
Settleables	6 ml/1	4 ml/1	2.96 ml/1	0.494
Conductivity	164 μmhos/cm	14 μmhos/cm	10.35μ mhos/cm	0.063

A recording raingauge was installed at the center of the pilot sector, atop the fourth floor of the Jewish Home for the Aged. An enlarged collector was fitted to the raingauge in order to increase its sensitivity to 0.001 inch of rainfall.

During the early portion of the wet weather period, rainfall data obtained from the project raingauge were compared with U.S.W.B. data from the Federal Office Building station. The relationship between the two sets of data are shown in Figure IV-9. It can be seen that the project raingauge gave consistently higher readings than the U.S.W.B. reported. However, the difference was only about 10 percent, and this could easily have resulted from topographical effects. Because the project raingauge became inoperative during a few storm periods, the U.S.W. B. data have been used in place of project raingauge data. This should not affect the accuracy of the results significantly, since the difference between the two sets of data has been found to be small.

Rainfall data for the monitoring at Laguna Street were acquired with a small portable raingauge located at the monitoring station. The apparatus consisted of a 200 sq cm collecting cone attached to a 250 cc graduate cylinder. The raingauge was situated in an open parking lot and the nearest major structure was approximately 300 feet away. Manual readings of the volume of rain collected were made at 10-minute intervals or in some cases 5-minute intervals.

Laguna Street

As mentioned earlier, the Laguna Street Area served as the secondary system in the storm overflow studies. Only two storms were monitored in this outfall. The flow determinations were accomplished by measuring the depth of flow at the outfall sewer and calculating the discharge by means of Manning's equation. Attempts to use the portable current meter were futile because of the extremely high velocities of flow occurring in this outfall sewer (estimated to be as great as 20 fps).

The use of Manning's equation was justified for the following reasons:

1. The slope of the outfall sewer is approximately two percent.

2. A uniform reach extends about 700 feet horizontally upstream from the point at which depths of flow were determined.

Hence the invert slope and the energy gradient were essentially identical, and the assumption of uniform flow was appropriate for the situation.

Grab samples were obtained manually, and sample preparation, storage, and analyses were done according to the methods described for the Selby Street monitoring station.

SPECIAL STUDIES

Receiving Water Coliform Studies

Receiving water coliform studies were conducted on a segment of the municipal marina located adjacent to the Laguna Street Outfall. The body of water in question, as shown in Figure IV-10, is relatively confined, with a breakwater barrier extending across the bay side of the harbor. The area of the marina lying within the breakwater amounts to approximately 12 acres, and the mean water depth is in the range of 20 ft.

Prior to evaluating the effects of combined sewer overflows on coliform levels in the marina, background samples were collected during two 24-hour periods of dry weather. These were made in conjunction with the coliform monitoring in the Laguna Street Sewer, and both confirmed and fecal coliform determinations were made. Seven stations were established in the area; five within the marina and two in the Bay, as shown in Figure IV-10. Each station was sampled at three hour intervals during the two 24-hour monitoring periods.

Wet weather monitoring was carried out on nine consecutive days during a rainy period beginning 10 March 1967. During this period rainfall occurred on five days. Overflows at the Laguna Street outfall were monitored on 10 March and 15 March, and the receiving water stations were sampled twice daily on each of the nine days. Both confirmed and fecal coliform tests were performed on each sample.

TREATMENT OF COMBINED SEWER OVERFLOWS

In San Francisco the principal pollutional effects from combined sewer overflows result from the following:

1. Potential pathogenic agents.
2. Floatable macroscopic particulates.
3. Floatable oils and greases.
4. Settleable decomposable materials.
5. B.O.D.
6. Suspended materials (turbidity).

Several candidate processes were evaluated in terms of reducing the aforementioned constituents in combined sewer overflows. They were:

Storage: The results from Selby Street consistently indicated that after a period of approximately two hours the mass rates of discharge of the various constituents were greatly reduced. Therefore, if the initial portions of the flow were diverted to a storage facility, a major fraction of the pollutional load would be prevented from entering the receiving waters.

Preliminary analyses showed that for all except very small storms the required storage volume would be impossible to obtain in San Francisco. The size (hence the cost) of such facilities would be prohibitive. An additional detrimental aspect of the scheme would be the necessity of providing the capacity for rapid removal of the accumulated runoff in preparation for subsequent storms. The program at Selby Street indicated that the length of the antecedent dry period is inconsequential beyond about one day. Hence the storage basin would have to be emptied in this period of time.

Sedimentation: In order to restrict the dimension of a treatment unit, it is imperative that a continuous flow scheme be employed. Sedimentation was the first process to be examined. Analyses of the settleable material in Selby Street overflows had indicated that a substantial improvement could be expected if the settleable fraction could be separated from the liquid stream (See Table V-5). However, based on experiences with primary clarifiers, surface loading rates would be in the range of 1,000 to 2,000 gsfd, which would require prohibitively large structures.

Screening: The passage of greases and oils would make the screen ineffective in achieving a principal objective.

Dissolved Air Flotation: The dissolved air flotation process has many features which make it a particularly attractive candidate for the treatment of combined sewer overflows. Among its favorable aspects are the following:

1. Floatable materials, including oils and greases are selectively removed. This degree of treatment alone would virtually solve the aesthetic nuisance problem caused by combined sewer overflows.

2. Other particulate materials are caused to float via nucleation and growth of air bubbles on the surface of the materials. Thus sludge forming constituents can be stripped from the waste stream, and concomitant reductions in BOD, nitrogeneous compounds, etc., can be expected.

3. Relatively high surface loading rates (6,000 gsfd or higher) can be employed. This contrasts with the low surface loading rates (2,000 gsfd or lower) that can be used with any degree of success in conventional sedimentation basins. Hence, the dissolved air flotation process would allow the use of much smaller treatment units than possible with conventional sedimentation. This factor is extremely important in high density urban areas, where land use is greatly restricted.

Therefore, laboratory scale tests were carried out to establish the general feasibility of the process and to obtain preliminary estimates of process efficiency under a range of operating conditions.

The tests were carried out as follows:

An aliquot of the sample was pressurized to 50 psig. The aliquot was then agitated to dissolve air in the fluid. Following this the air pressure was released, causing dissolution of air and flotation of particulates. The float was removed, and the aliquot was used as the recycle fraction for the remainder of the analysis.

The stripped aliquot was then repressurized, agitated, and added in various ratios to raw waste in a 1000 ml graduate cylinder. When discharged into the raw waste, the pressurized aliquot released dissolved air throughout the sample, causing flotation to occur. Samples were withdrawn at the 350 ml level at various times after the addition of the pressurized cycles. These were analyzed for COD and grease.

LABORATORY PROCEDURES

Analyses of the samples usually commenced upon delivery of the samples to the laboratory. If storage was found to be necessary, the samples were refrigerated at a temperature less than 4^{o} C and the storage was not allowed to exceed 48 hours.

The tests designated in Table IV-3 were conducted regularly on all the samples taken of the dry weather flow as well as the wet weather flow.

Special schedules were followed for coliform analyses, as previously described. In addition, fish toxicity bioassay tests were conducted on a limited number of dry and wet weather samples.

Analytical Methods

The methods used for the regularly scheduled tests are shown in Table IV-3. A modified method was followed for the COD and grease determinations. The procedures are described in Appendix B.

After consideration of the alternate method for coliform analyses, including the membrane filter technique, it was decided to use the standard multiple tube MPN procedure. The reasons for this choice were :

1. The MPN procedure is widely used, hence a uniform basis for comparison with other studies was ensured.

2. The laboratory was geared to this test, and all the necessary apparatus was on hand.

3. Examination of extensive data from other public agencies disclosed that inconsistently lower results are obtained from membrane filter counts as compared with the MPN figures from concurrently inoculated fermentation tubes. The inconsistency could not be tolerated in the proposed program since only limited sampling was to be done.

It was also decided to modify the confirming step of the standard fermentation tube procedure in order to differentiate fecal coliforms from coliforms from other sources. It was felt this would be of substantial value in interpreting the analyses of the runoff and receiving water samples. This is demonstrated by the data shown in Figure IV-11 which were obtained from urban runoff discharged from a separate storm water sewerage system (7). It is obvious that substantial non-fecal coliform concentrations exist in the runoff reaching sewer inlets and, using conventional techniques, it would not be

TABLE IV-3

ANALYTICAL METHODS

Analysis	Method Used	Reference
BOD	Dilution	
COD	Modified Digestion	Appendix B
SS	Glass Filter	SERL and Methods (15)
VSS	Glass Filter	SERL and Methods (15)
Settleable Solids	Imhoff Cone	
Grease	Liquid-Liquid Extraction	Appendix B
Floatables	Gravimetric	Appendix B
Nitrogen	Standard	
Phosphate	Colorimetric	
Alkalinity	Standard	
Conductivity	Standard	
Sodium	Flame Photometric	
Potassium	Flame Photometric	
Calcium	EDTA	
Magnesium	EDTA	
Sulphate	Turbidimetric	
Chloride	Mecuric Nitrate	

possible to distinguish the runoff contribution from the sewage contribution in the overflow.

In order to make the differentiation, confirmed tests were carried out at an elevated temperature, 44 - 45°C, in Bacto EC (E. Coli) Media (Difco B314), as well as by the Standard Methods confirmed test procedure. Two tubes per dilution and three dilutions were made for each sample.

The fish used in the bioassay tests were Gasterosteidae (Sticklebacks) and the tests were run for 96 hours according to procedures given in Standard Methods (16). The samples were aerated to eliminate dissolved oxygen depletion. Four dilutions of each sample were utilized in each test.

Estimate of Laboratory Errors

An analysis was made of the variations in analytical results from replicate samples. Because of the small number of samples involved, the estimates of standard deviation were based on the range of values rather than using the sum of squares technique. The results of these analyses are shown in Table IV-4.

TABLE IV-4

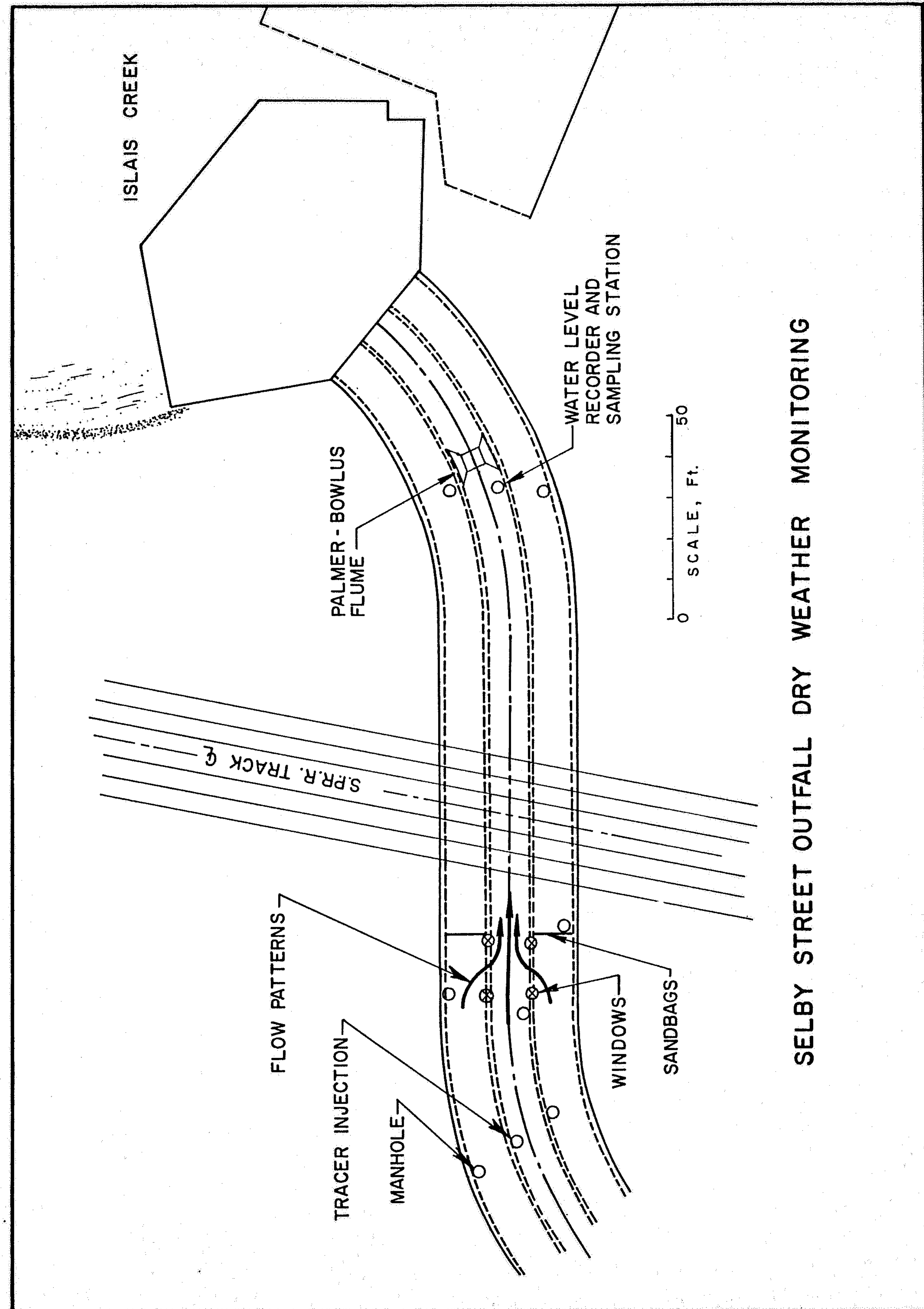
ESTIMATION OF LABORATORY ANALYTICAL ERRORS

Test	Mean Value(s)	Number of Samples	Number of Repetitions	Estimate of Standard Deviation
Phosphate (PO_4)	3.27 mg/1	1	6	0.055 mg/1
Susp. Solids	203.0 mg/1	1	10	10.1 mg/1
Volatile Susp. Solids	123.4 mg/1	1	10	3.8 mg/1
Grease	5.73, 17.67 mg/1	2	3	1.70 mg/1
NH_3 -N	7.35 to 9.45 mg/1	5	2	0.36 mg/1
Organic - N	3.33 to 6.48 mg/1	5	2	0.99 mg/1
Floatables *	2.7 mg/1	1	5	0.4 mg/1
	49 mg/1	1	5	2.8 mg/1
COD	91 to 560	12	2**	13.4 mg/1

* Results from developmental work, September 1965 (17).

** From correlation analysis - one repetition for each method.

FIGURE IV - I



SELBY STREET OUTFALL DRY WEATHER MONITORING

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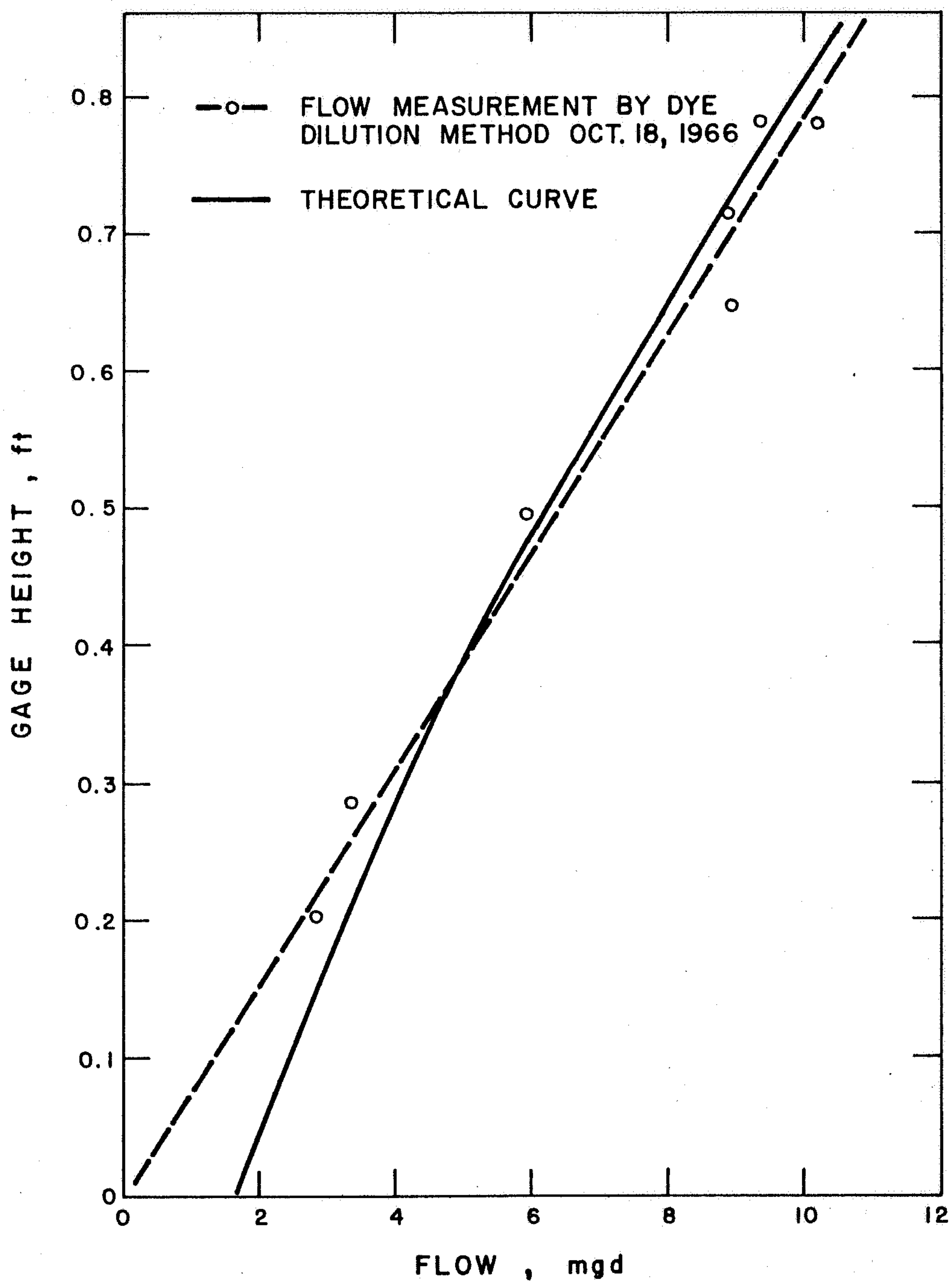
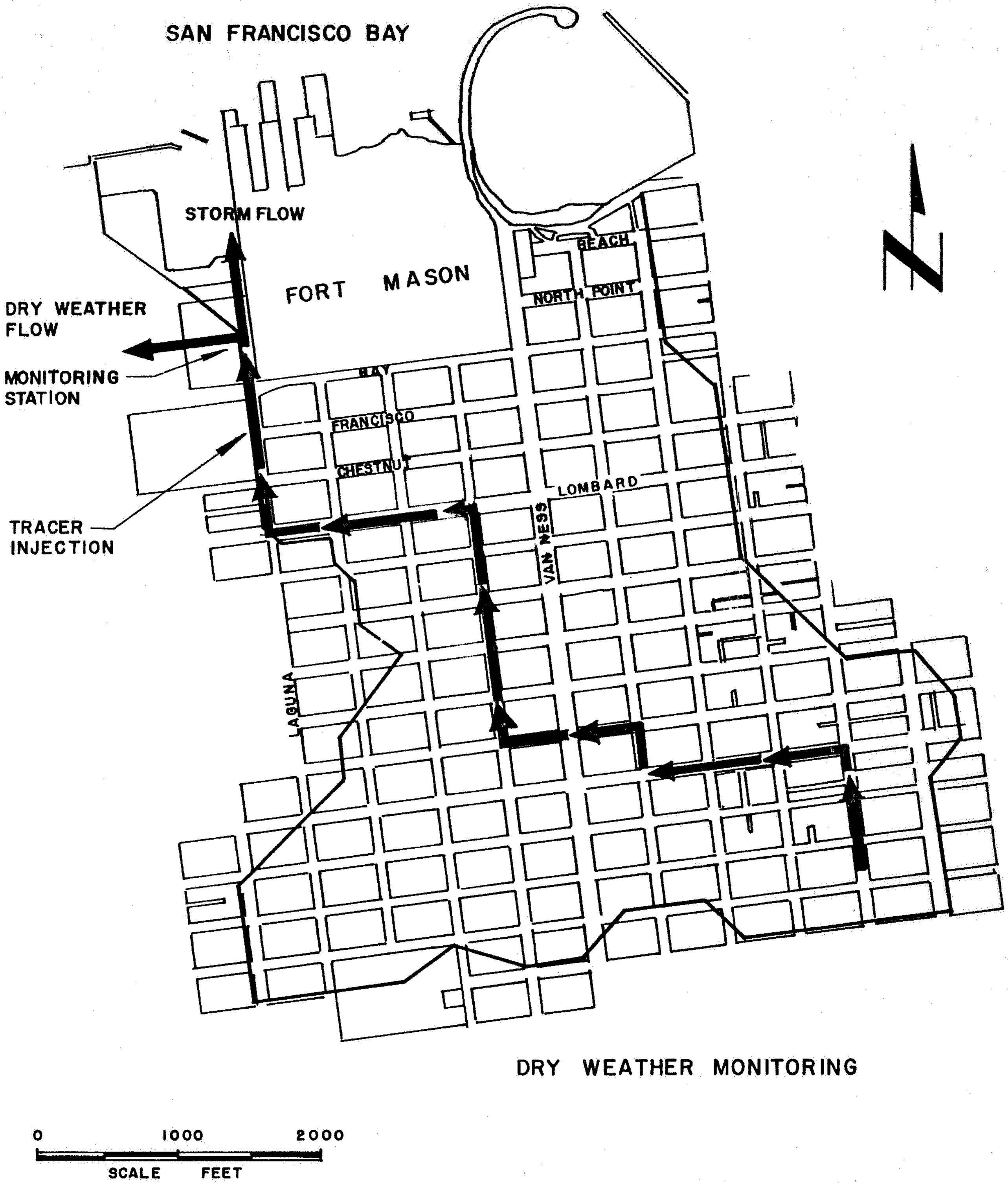
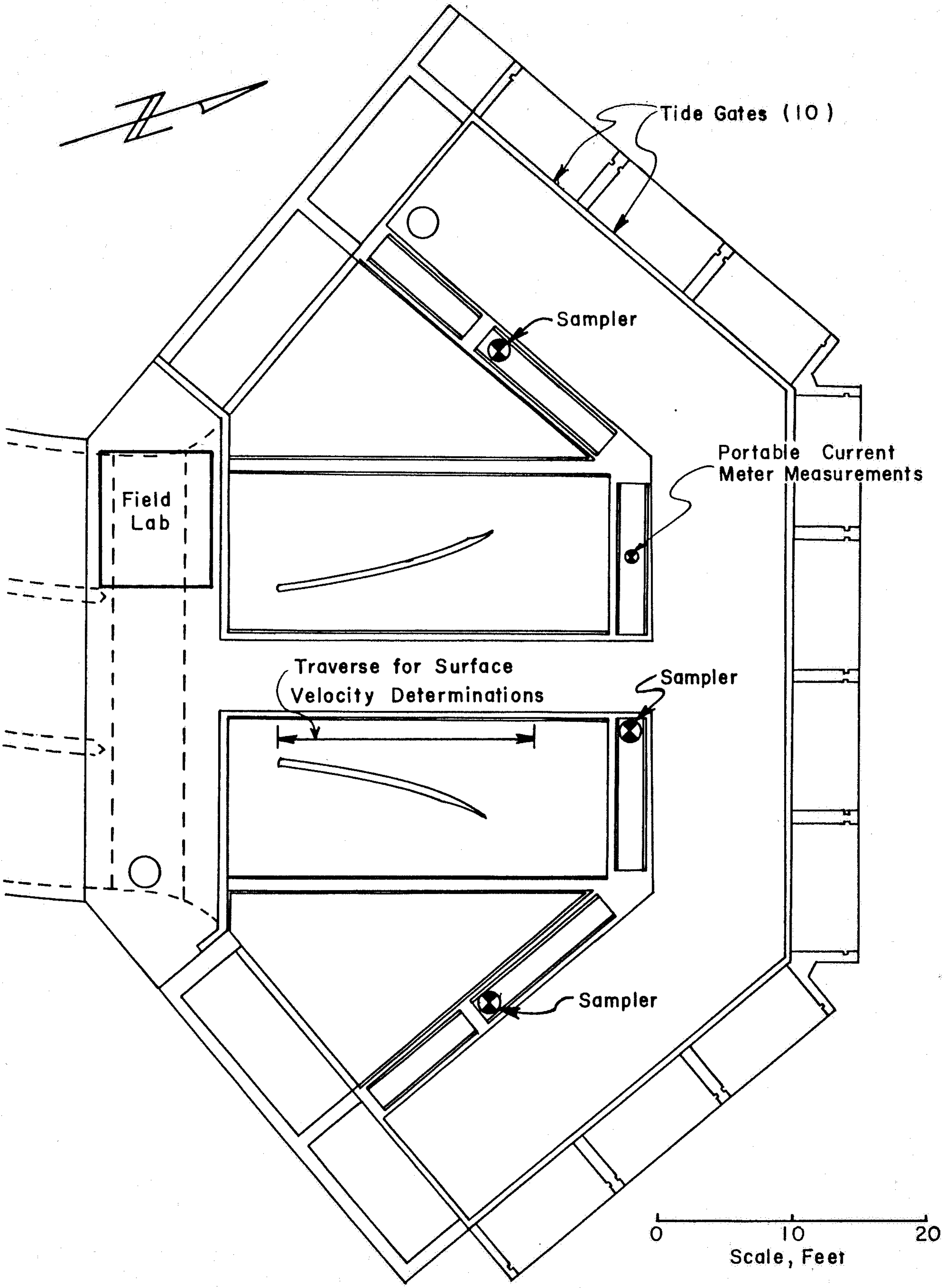


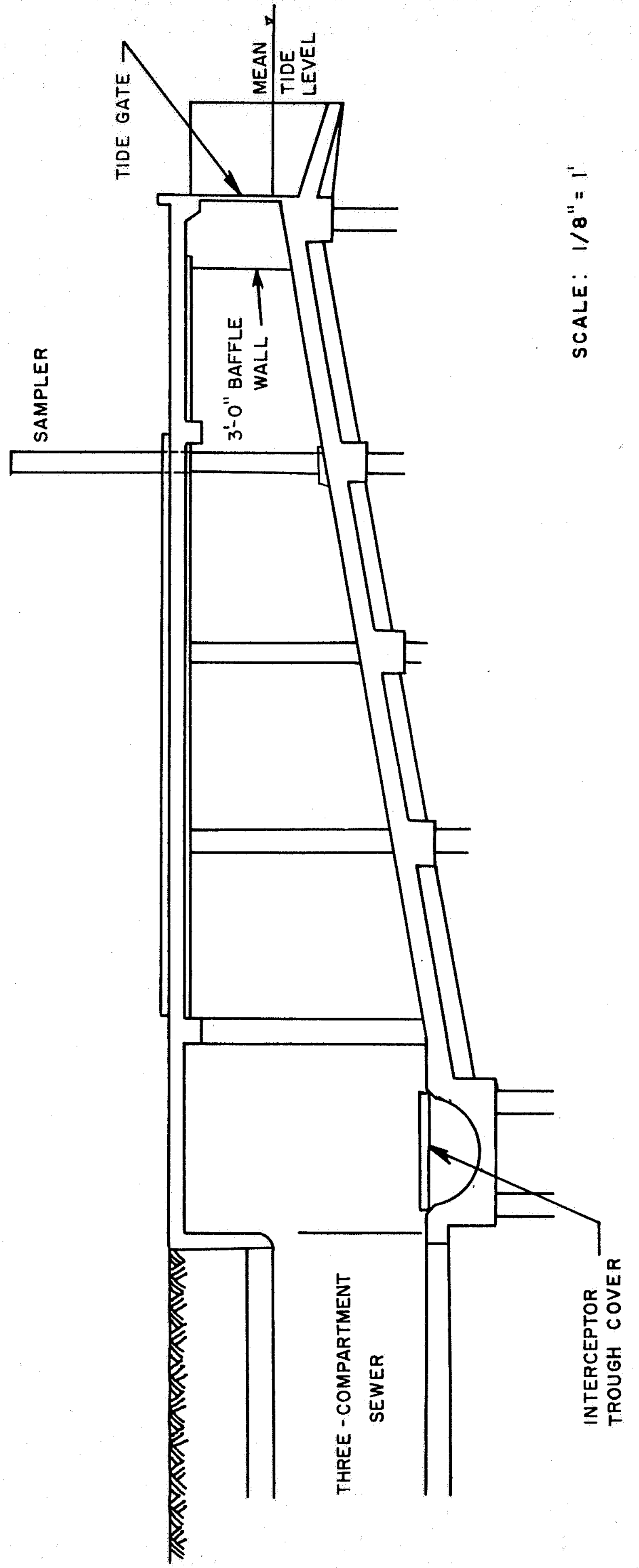
COMBINED SEWER OVERFLOW STUDY, SAN FRANCISCO
SELBY STREET OUTFALL
PALMER - BOWLUS FLUME CALIBRATION CURVE



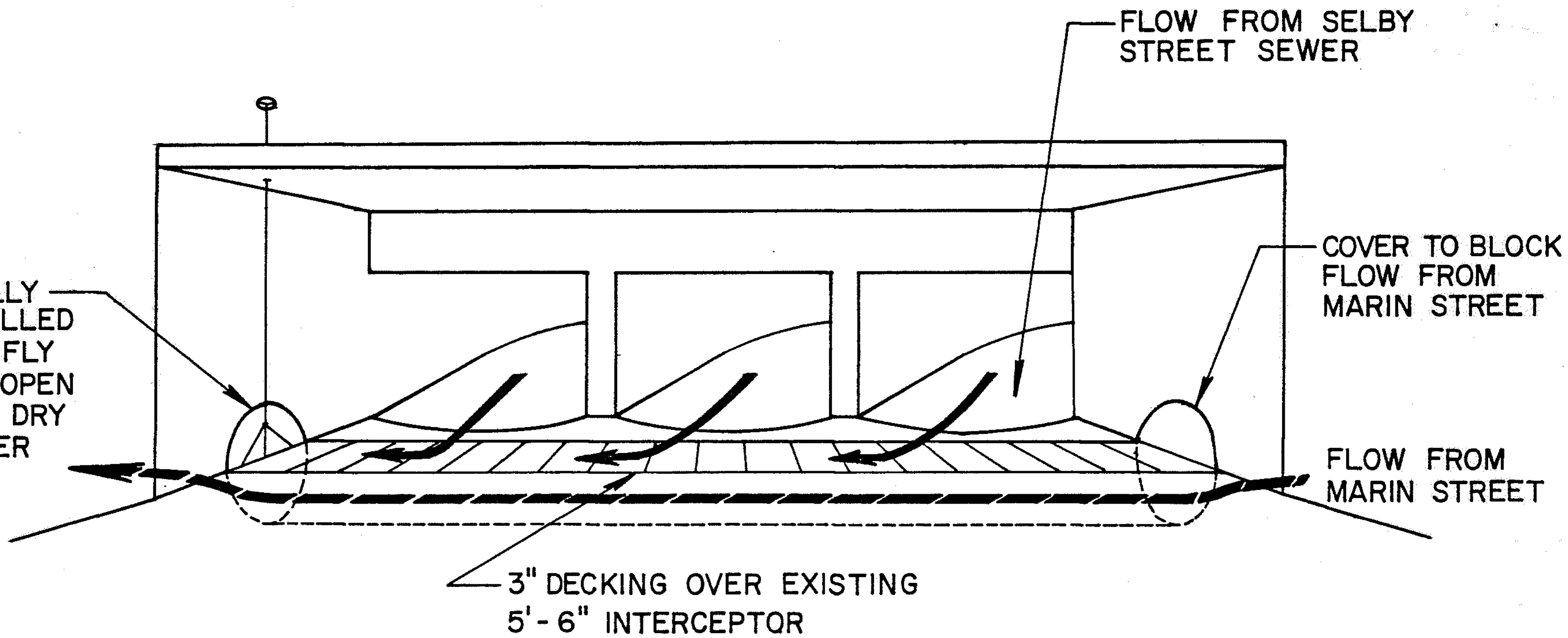
LAGUNA STREET OUTFALL DRY WEATHER MONITORING



WET WEATHER MONITORING
SELBY STREET DIVERSION STRUCTURE



CENTER-LINE SECTION OF SELBY STREET DIVERSION STRUCTURE

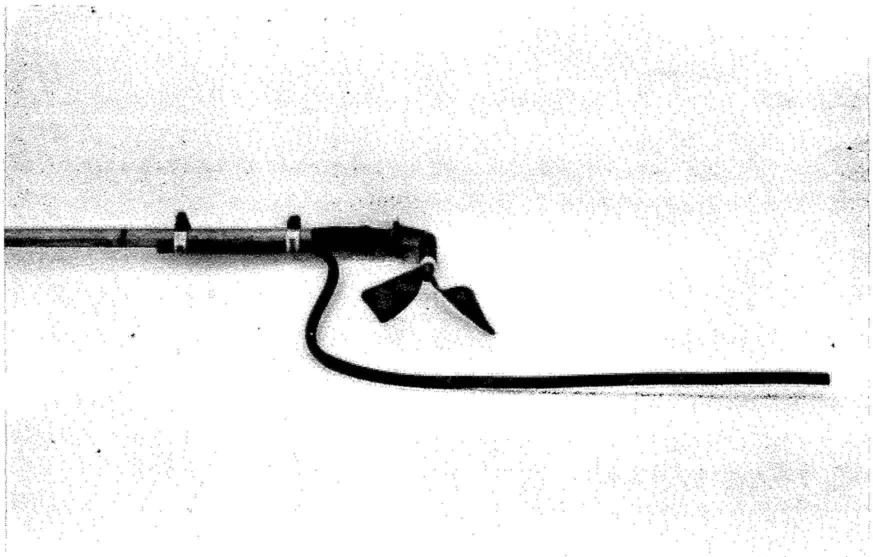


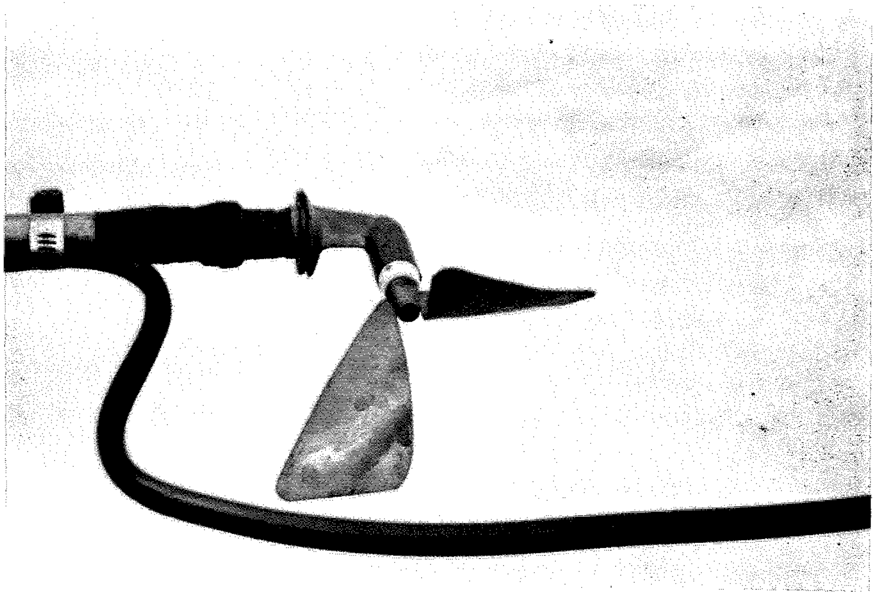
SELBY STREET DIVERSION STRUCTURE MODIFICATIONS

NOT TO SCALE

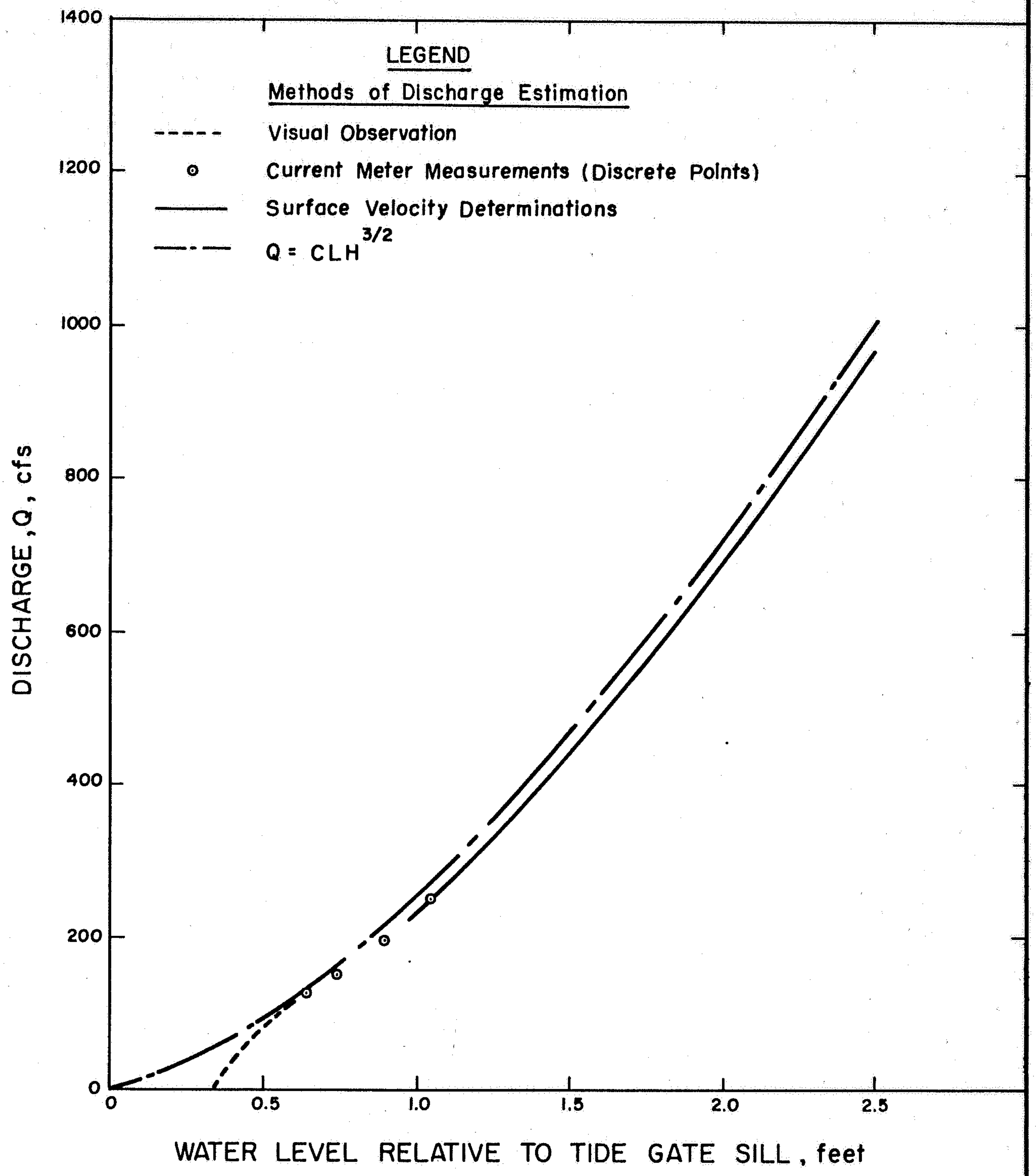
ENGINEERING - SCIENCE, INC.

FIGURE IV-6

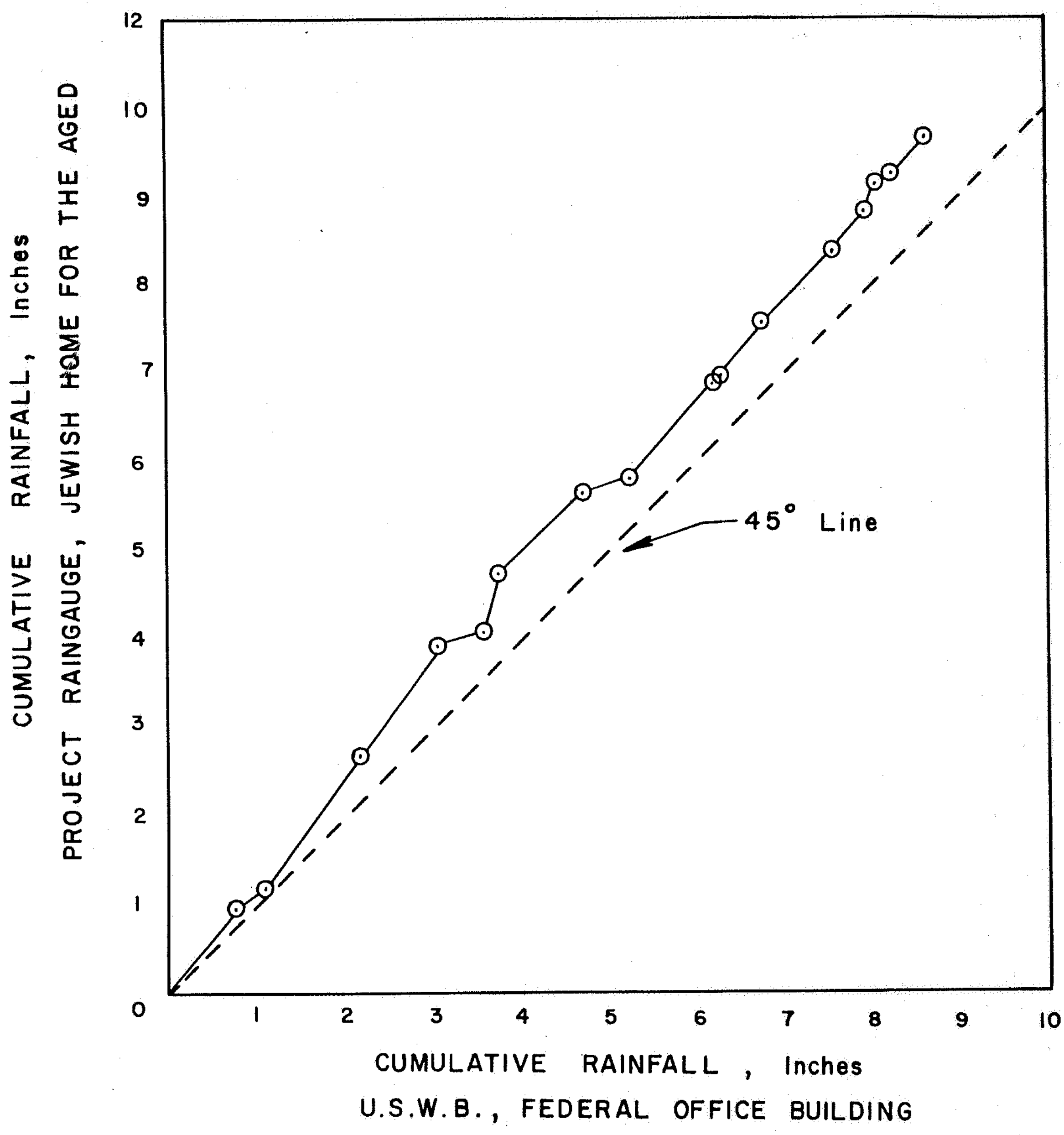




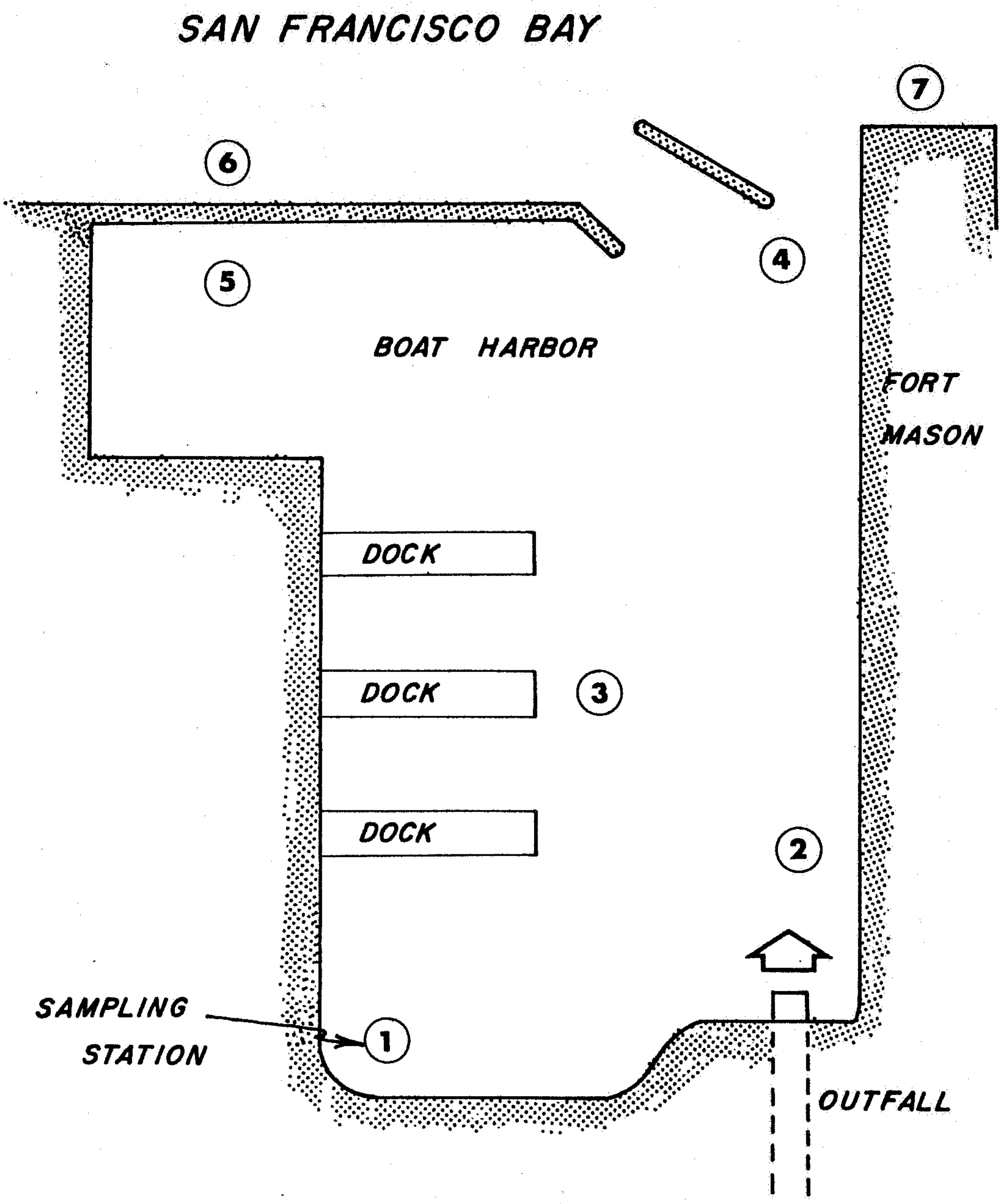
PORTABLE CURRENT METER
USED AT SELBY STREET



SELBY STREET OUTFALL DISCHARGE RATING CURVES

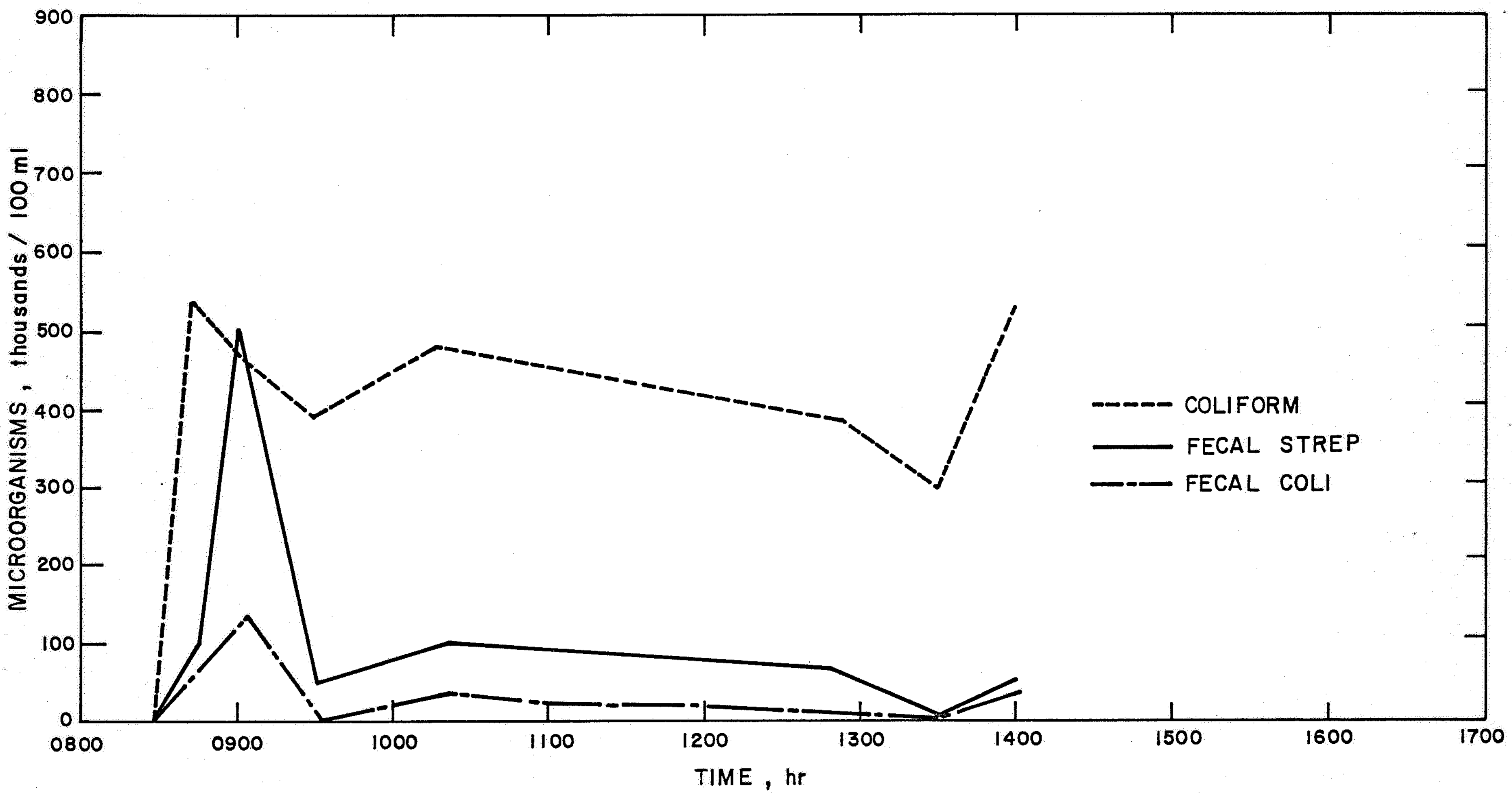


COMPARISON OF RAINGAUGE DATA



LAGUNA STREET

RECEIVING WATER SAMPLING STATIONS



URBAN STORMWATER RUNOFF FROM 27-ACRE RESIDENTIAL AND LIGHT-COMMERCIAL AREA, CINCINNATI, OHIO (7)

FIGURE IV-11

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CHAPTER V

DATA PRESENTATION AND EVALUATION

DRY WEATHER MONITORING

Flow

The observed rates of flow in the two pilot sectors were averaged for selected time periods and are shown in Figures V-1 and V-2. The Selby Street data were considered separately for weekdays (Monday through Friday) and weekend (Saturday and Sunday) periods, whereas no distinction was made for the Laguna Street sector. The data show typical urban flow variations exhibiting maxima during morning and evening periods and a principal minimum between 5:00 to 7:00 A.M. Average per capita flows were:

Sector	Average per capita Flow (gallons per day)
Selby Street	96
Laguna Street	107

The higher per capita value in the Laguna Street sector most likely results from a higher proportion of water-consuming commercial establishments such as restaurants, laundries, etc.

Physical-Chemical Composition

Sewage characteristics were determined in terms of the constituents listed in Table IV-3. The weekday diurnal variations of COD, BOD, SS, VSS, Grease, Floatables, Nitrogen, and Phosphates are shown in Figures V-3 through V-6. Individual values for one-hour periods were averaged for the Laguna Street data, whereas the Selby Street values were grouped in intervals of three hours. Data for each monitoring period are included in Appendix C. These quality variations are characteristic of urban areas, reflecting normal human activity patterns.

The average flow rate and concentration data were combined for the calculation of mass discharge relationships. These were used to compute the relative contribution of normal sewage flows to wet weather discharges, average dry weather per capita contributions, and flow-weighted mean constituent concentrations. The latter two are included in Table V-1. The per capita values and average concentrations shown in Table V-1 are similar to other reported values (18 and 19), indicating that the systems studied are not unique in terms of normal dry weather sewage flows.

Coliforms and Bioassay

Diurnal coliform variations are shown in Figures V-7 and V-8. For both pilot sectors the data are plotted as log mean MPN's from two days of monitoring.

TABLE V-1

AVERAGE DRY WEATHER CONDITIONS

Constituent	SELBY STREET SYSTEM: Weekdays, Mean Concentration (mg/l)	SELBY STREET SYSTEM: Weekdays, Lbs per Capita per Day	SELBY STREET SYSTEM: Weekends, Mean Concentration (mg/l)	SELBY STREET SYSTEM: Weekends, Lbs per Capita per Day	LAGUNA STREET SYSTEM: Weekly, Mean Concentration (mg/l)	LAGUNA STREET SYSTEM: Weekly, Lbs per Capita per Day
COD	456	0.365	465	0.372	430	0.383
BOD	164	0.131	177	0.142	179	0.159
SS	209	0.167	202	0.162	194	0.173
VSS	148	0.118	146	0.117	162	0.144
Floatables	3.0	0.0024	3.2	0.0026	2.8	0.0025
Grease	45	0.036	27	0.022	45	0.040
Nitrogen (N)	32	0.025	33	0.026	31	0.028
Phosphate (PO_4)	9.1	0.0073	8.1	0.0065	7.9	0.0070

There is no clear cut explanation for the order of magnitude difference between the numbers of total confirmed coliforms and fecal coliforms. Authoritative reports (20) indicate the fecal coliform procedure (EC media at 44 - 45°C) to be sensitive to about 96 percent of the coliforms originating in the human intestine. Therefore, although there has been no known study of the levels of fecal coliforms in domestic sewage, one would expect domestic sewage to have a ratio of fecal to total coliforms of near unity. The observed total confirmed coliform MPN's are in line with reported values ($5- 7x10^5$ per ml) and the average per capita emission rates were calculated to be:

Pilot Sector	Total Confirmed Coliforms Average Per Capita Emission Rate
Selby Street	$203x10^9$ per day
Laguna Street	$190x10^9$ per day

These values are also typical (18).

In order to judge the relative significance of the results of bioassay tests conducted on wet weather overflows, a limited number of analyses were performed on dry weather samples. The results are presented in Table V-2. The six-fold increase in sewage strength from 7:00 A.M. to 8:45 A.M. was accompanied by a decreased median toxic limit (TL_m). Comparisons with storm overflow bioassay results are included in a subsequent section of this report.

TABLE V-2

BIOASSAY TEST RESULTS - SELBY ST. SYSTEM, DRY WEATHER FLOW

Sample Time	COD, mg/1	Time, hrs.	TL_m (Percent by Volume of Sample)
7:00 A.M.	72	24	> 75
		48	> 75
		72	> 75
		96	> 75
		120	> 75
8:45 A.M.	450	24	62
		48	39
		72	39
		96	38
		120	38

The general conclusion drawn from the results of the dry weather monitoring program is that both sectors, although having different patterns of land use and population density, do not have unusual dry weather sewage flows in terms of either averages or variations of both flow rate and sewage physical-chemical-biological characteristics.

WET WEATHER MONITORING

Hydrology

Utilizing the project raingauge and flow measurement data (and occasionally information from the U.S. Weather Bureau), runoff factors relating total runoff to total rainfall have been calculated for each storm monitored. This information is shown together with the antecedent dry period for each storm in Table V-3. Figures V-9 through V-13 depict the rainfall-runoff rates for each storm. No attempt was made to correlate the calculated runoff factors with other storm parameters. It should be noted that the storage capacity of the Selby Street Trunk sewer was calculated to be 12.2 acre feet, which is equivalent to 0.043 inches of runoff, or approximately 0.07 inches of rainfall for the entire 3,400 acre sector. This tends to reduce the runoff factor for storms of small magnitude as a significant portion of the runoff may not overflow. Because the monitoring of the Laguna Street Outfall was carried out only twice, whereas at Selby Street eight storm flows were monitored, it was believed that the runoff factor computed for the Laguna Street sector should be adjusted to eliminate the bias introduced by the utilization of so few data points. The most rational method for making such an adjustment would consist of comparing the data for both sectors under identical meteorological conditions and using the two sets of data and the average data from Selby Street as a basis for adjustment. The Selby Street system was monitored on the same dates as the Laguna Street sector, and this is as near as one could expect meteorological conditions to be equivalent. Therefore, the comparison was made with the Selby Street rainfall-weighted mean runoff factor for the two periods in question: 10 March 1967 and 15 March 1967. The flow-weighted mean runoff factor for these two periods at Selby Street was 25.4 percent, as compared to 40.2 percent at Laguna Street. Hence the mean runoff factor for the Laguna Street sector is most likely in the vicinity of 70 percent, as compared with the overall mean of 59.2 percent computed from the Selby Street data. This is consistent with the relative imperviousness of the two pilot areas.

Physical-Chemical Characteristics

Based on analysis of individual storm data, the nature of the overflows can be qualitatively described as follows: As runoff commences, the mass of sewage in the downstream reaches of the sewerage system is virtually forced as a plug to the overflow structure. Consequently, the initial overflows generally have the characteristics of raw sewage.

The concentration of constituents in the initial overflows are, however, affected by the rate of buildup of stored runoff in the sewerage system. Slow runoff rates result in higher initial pollutant concentrations. For example, on 24 February approximately six hours elapsed between the beginning of rainfall and the commencement of overflow. The initial COD was 1,762 mg/l, about four times the dry weather average.

If flows are sufficient, the initial (sewage) phase is followed by a period of scour of materials from the sewer. A majority of the surface debris is also swept into the sewer system with the initial portions of intense

TABLE V-3

HYDROLOGIC DATA FOR MONITORED STORMS

System	Date of Storm	Rainfall (inches)	Runoff Factor (percent)		Antecedent Dry Period (days)	Runoff Duration (hours)
Selby	6 Nov 66	0.98	35.8		50	4
	14 Nov 66	0.42	59.6		0	4
	15 Nov 66				1/2	4
	20 Jan 67	3.92	81.3		42	36
	23 Jan 67	0.72	84.6		1-1/2	8-1/2
	24 Feb 67	0.22	13.7		11	2-1/2
	10 Mar 67	1.34	20.2	25.4	7	*
	15 Mar 67	0.74	34.8		< 1	*
	Flow-weighted mean		59.2			
Laguna	10 Mar 67	1.01	34.6		7	*
	15 Mar 67	0.81	47.3		< 1	*
	Flow-weighted mean		40.2			
	Adjusted mean**		70			

*Not measured.

**See Text.

runoff. Consequently, overflows during the second phase are qualitatively the worst. It has been found that during the period the concentrations of the various constituents in the overflows rise from 150 to 200 percent of the average dry weather flow values. The levels of pollutants then decrease to steady-state values, which are in the range of 10 to 25 percent of dry weather flow values and most likely characteristic of surface runoff sequent to the initial washing.

The time of decrease to steady-state levels, or decay time, has been found to be relatively constant and independent of the magnitude of the rainfall or rate of discharge (so long as flow is sustained for this period of time). For the Selby Street system the decay time is about double the time of concentration, or approximately 100 minutes.

A plot of data obtained at Selby Street during the monitoring of the storm of 6 November 1966 is shown in Figure V-14. The three phases described above are clearly displayed in the plots of COD, BOD, SS, and VSS. These patterns were displayed for most of the remainder of the storms monitored. The data are included in Appendix D.

Based on the analysis of eight storms in the Selby Street pilot sector, calculations were made to determine the average characteristics of combined sewer overflows as a function of time relative to the commencement of overflow. For averaging purposes, the monitoring data were grouped into the following categories:

Time Relative to Commencement of Overflow (minutes)	Flow Rate (cfs)
0-10	< 100
10-20	100-200
20-30	200-400
30-40	> 400
40-50	
50-60	
60-80	
80-100	
100-120	
120-140	
140-170	
170-200	
> 200	

For each time increment, a mean concentration was computed by averaging the means of each flow rate increment.

The lengths of the time increments were based on a subjective evaluation of the rates of change of constituent concentrations. A detailed analysis of rainfall intensity-frequency relationships previously developed by the City of San Francisco, indicated that approximately equal amounts of runoff occur in each of the selected flow rate increments, i.e., approximately 25 percent of the average annual runoff from the Selby Street Pilot Sector occurs at flow rates less than 100 cfs, etc. Thus, if sufficient data were accumulated, this technique would provide flow-weighted mean concentrations for each time interval. The only question remaining concerns the adequacy of the collected data. Subsequent research will be directed towards an analysis of time-intensity relationships of individual storms, so that more accurate time-concentration data can be developed. It was observed that storms preceded only by a short rainfall hiatus produced distinctly different overflow qualities than did storms with a longer antecedent dry period. Moreover, it was found that the critical antecedent dry period was approximately one day. That is, very little difference could be detected between overflows following a dry spell of 1.5 days and overflows from storms occurring after much longer periods of dry weather (up to 50 days). Consequently, for purposes of calculating average overflow characteristics the storm data were separated into two categories: those with antecedent dry periods of less than one day, and those preceded by 1.5 to 50 days of dry weather. The breakdown was shown in Table V-3.

The average concentration-time data are plotted in Figures V-15 through V-19. Dry weather averages are also shown for comparative purposes. Because of a few extremely high strength initial overflows, Phase I is not apparent in the average plots. However, Phases II and III are quite distinct. It is clear that if storage of the initial 100 minutes of overflow could be achieved, it would be possible to reduce by a large factor the mass of materials discharged to the receiving waters.

The limited data collected at the Laguna Street outfall are in close agreement with the Selby Street observations, although there are some significant differences. Because only two storms were monitored at Laguna Street, average constituent concentration data have not been computed. A comparison between the two sectors is included in a subsequent section on mass discharges. Appendix D contains a complete tabulation of wet weather data from both pilot sectors.

Coliforms

Coliform analyses were conducted on samples from only four storm periods (the last four) at Selby Street and two at Laguna Street. The results are tabulated in Appendix D with the physical-chemical data. Composite plots of the Selby Street total and fecal coliform data are presented in Figure V-20 and Laguna Street data are shown in Figure V-21. These plots were prepared in the same fashion as the physical-chemical plots (Figures V-15 through V-19). However, the individual data points were not flow weighted, and geometric mean values were computed for each time interval. Because of the limited field data, a more sophisticated analysis was not justified.

Notable features of the coliform densities were the continuing decline of coliform concentrations after most other constituents have reached their steady-state values.

Special Analyses

Bioassay Tests: Three samples from the Selby Street overflow of 24 February 1967 were subjected to acute toxicity fish bioassay analyses. The test fish were Gasterosteidae (Sticklebacks), and the tests were conducted for 96 hours with continuous aeration of the test vessels to eliminate dissolved oxygen depletion.

Fish kills increased with the strength of the overflow, as shown in Table V-4. The samples in which fish kills occurred had extremely high turbidities. It is therefore quite possible that kills were due to a physical obstruction of the gill surfaces of the fish, rather than chemical toxicity.

TABLE V-4

BIOASSAY TEST RESULTS
SELBY ST. SYSTEM, WET WEATHER OVERFLOW

Sample	Time After Commencement of Overflow	COD (mg/1)	TL_m Time hrs.	TL_m Percent by Volume
2-24-S-1	10 min	1,762	24	> 50
			48	> 50
			72	50
			96	35
2-24-S-2	20 min	1,275	24	> 50
			48	> 50
			72	> 50
			96	> 50
2-24-S-3	30 min	603	24	> 50
			48	> 50
			72	> 50
			96	> 50

The high strength sample was not significantly worse than the peak flow dry weather sample (Table V-2). Based on this limited information, it might therefore be concluded that it is highly probable that combined sewer overflows pose no acute toxicity threat, provided the dry weather flows contain no large concentrations of toxic materials from industrial discharges.

Chlorine Demand Analyses: Chlorine demand tests were carried out on four samples from the January 20th storm, and the results are shown in Figure V-22 as a function of the particular COD. The condition of 4 mg/1 residual after 10 minutes of contact had been established by the City as being sufficient to reduce coliform levels to less than 10 per ml in discharges from the sewage treatment plants.

The coliform level of less than 10 per ml was chosen as the acceptable level, since 10 per ml is highest level of coliform concentration allowed in waters to be used for contact sports. The COD of the overflows during the initial phase averaged to 800 mg/l and later the value normally levelled off at about 250 mg/l (see Figure V-15). Using these as the extreme ranges it is concluded that 10-15 mg/l of chlorine would be sufficient to obtain the desired residual in the combined sewer overflow (see Figure V-22). However, further study is necessary to evaluate more precisely the bacteriocidal effects of chlorination of combined sewer overflows.

Macroscopic Particulates: Several analyses have been conducted on the materials settled during the floatables determinations and on the residual suspended materials. Mass removal relationships have been calculated from these results, and percent removals of volatile solids, COD, and BOD are tabulated in Table V-5. These data indicate the feasibility of physical treatment methods for the reduction of the pollutional level of combined sewer overflows. It can be seen that significant fractions of the BOD, COD, and VSS are associated with the macroscopic particulates in the overflow.

TABLE V-5

MACROSCOPIC PARTICULATE FRACTIONS OF COMBINED SEWER OVERFLOW CONSTITUENTS AS DETERMINED BY IMHOFF CONE SETTLING-SAMPLES FROM SELBY STREET

(V/TA_s = 110 gsfd)*

	Total Storm Mass Discharge (lbs)	Settleable (lbs)	Percent
I. VOLATILE SOLIDS			
20 Jan 67 (First 4 Hours)	24,000	17,300	72
20-22 Jan 67	77,500	63,500	82
23 Jan 67	28,000	23,400	84
II. COD			
20 Jan 67 (First 4 Hours)	55,500	38,200	69
20-22 Jan 67	198,000	136,600	69
23 Jan 67	46,000	18,800	41
III. BOD			
6 Nov 66	18,100	9,500	53

*V = Volume (1 liter) T = Settling Time (30 min)

A_s = Surface Area of Liquid in Cone

Mass Discharges

In order to establish quantitatively the significance of combined sewer overflows, as compared to other pollutional sources, specific mass discharge factors (lbs per acre-inch of runoff) were calculated for several of the important overflow constituents. A wide distribution of storms has been encountered in the monitoring program, and the calculated factors are most likely representative of average conditions.

The technique used in the computation of the mass discharge factors consisted of dividing the total mass of material discharged by the total volume of flow, i.e.,

$$\text{Mass Discharge Factor} = \frac{\Sigma\, Qc\, \Delta t}{\Sigma\, Q\, \Delta t}$$

These factors actually amount to flow weighted mean concentrations, expressed in more "convenient" units.

The specific mass discharge factors for individual constituents for both pilot sectors are shown for each storm monitored in Appendix E. Included are the values attributable to the storm conditions, that is, the normal dry weather flow mass discharges have been subtracted from the totals. The average mass discharge factors are summarized in Table V-6. The specific mass discharge factors for Laguna Street have been adjusted in the same manner as the runoff factor. For the Selby Street area mean values from the data of 10 to 15 March were compared with the overall mean values, ratios were computed, and the Laguna Street data were adjusted in proportion to these ratios. Here again it was assumed that similar meteorological conditions produced proportional deviations from the true mean values.

TABLE V-6

MEAN SPECIFIC MASS DISCHARGE FACTORS
(Lbs per Acre-Inch of Runoff)

Constituent	Selby Street Total	Selby Street Due to Storm**	Laguna Street Total	Laguna Street Due to Storm**
BOD	8.11	5.31	9.50*	4.04*
COD	35.8	29.8	33.5*	20.0*
SS	56.5	53.8	37.5*	32.1*
VSS	17.5	15.6	15.6*	10.8*
Floatables	0.97	0.93	0.79	0.65
Grease	2.92	2.54	2.83*	1.66*
Nitrogen	0.85	0.44	1.09*	0.31*
PO_4	0.190	0.084	0.229*	0.018*

*Adjusted Means (see text).

**Totals less estimated concurrent dry weather discharge. This amount of material was either contained in surface runoff or was removed from the stored deposits in the sewer system.

The average mass discharge factors and annual mass discharges for COD, BOD, suspended solids, volatile suspended solids, nitrogen, and phosphates are compared in Table V-7 with data reported by Weibel, et al (7) and Robeck (21) for urban surface runoff in Cincinnati. The three systems have the following rainfall and runoff quantities:

TABLE V-7

MASS CONSTITUENTS IN WET WEATHER DISCHARGES FROM URBAN AREAS

	Storm Runoff in Cincinnati		Combined Sewer Overflow, San Francisco			
			Selby System		Laguna System	
Constituent	lb/acre-yr+	lb/acre-inch runoff*	lb/acre-yr	lb/acre-inch runoff	lb/acre-yr++	lb/acre-inch runoff
BOD	33	2.01	101	8.1	136	9.50
COD	240	14.0	447	35.8	480	33.5
SS	730	45.6	632	50.7	540	37.5
VSS	160	10.0	218	17.5	224	15.6
N	8.9	0.56	10.6	0.85	15.6	1.09
PO_4	2.5	0.16	2.4	0.19	3.2	0.23
Grease	-	-	36.5	2.92	40.7	2.83

+ Weibel, et al (7)

* Calculated with an annual runoff of 16 inches (21)

** Calculated with an annual runoff of 12.5 inches

++ Calculated with an annual runoff of 14.4 inches

System	Annual Rainfall (Inches)	Annual Runoff (Inches)	Percent Runoff
Cincinnati	39.5	16.0	40.5
Selby St., S. F.	20.5	12.5	
Laguna St., S.F.	20.5	14.4	

Hence a direct comparison should be restricted to the specific mass discharge factors.

From Table V-7 it appears that the additional mass discharges from combined sewer overflows (over and above urban surface runoff) are significant for COD, BOD, and VSS, when compared to the contributions of storm runoff alone. As one would expect, the principal source of inorganic suspended solids appears to be surface runoff. Both nitrogen and phosphorus concentrations are higher in combined sewer overflows; however, the majority of these nutrients appear to be conveyed to sewer from the surface. Separation of storm and sanitary sewers would result in the sewage increment of the combined sewage to be in part removed by treatment.

Tables V-7 and V-8 lead to several at least tentative conclusions regarding the handling of storm runoff and sanitary sewage in urban areas. For example, in situations where secondary treatment has not been installed, municipal primary effluents annually contribute the major portion of organic pollutants and nutrients to the receiving waters. Here the separate sewerage system would contribute little to the overall reduction in organic discharge and might only be justified to protect certain localized areas not otherwise influenced by urban pollution. The same argument might also apply to the suggestion that the overflows be individually treated. However, when secondary treatment is practiced, the annual discharge of organics resulting from overflows of untreated sewage may nearly equal those from the secondary plant serving the area. Moreover, the annual discharge of organic pollutants in surface storm runoff, especially the suspended matter, may considerably exceed that from secondary effluents or from untreated sewage overflows. In the case of nutrients, both primary and secondary municipal effluents remain as the major source in urban areas. Thus, from the standpoint of the annual discharge of organics into sensitive receiving waters that also receive either primary or secondary effluents, storm drain and sanitary sewer separation does not appear to be justified. It would be more effective to use combined sewers, to minimize overflows by increasing interceptor and treatment plant capacities, and to provide some treatment for the overflows, especially where these occur in sensitive areas.

A consideration of the transient effects of combined sewer overflows may lead to a somewhat different conclusion from that of the previous paragraph, although not necessarily. Releases of large quantities of suspended and dissolved organics, floatables, and coliform organisms in short periods of time and at unsuitable locations may of course create unacceptable local problems. Rainfall sufficient to cause overflows in San Francisco occurs approximately 40 days per year, and the average annual runoff amounts to about 30 percent of the average sewage flow and during storm periods runoff is an order of magnitude greater than normal sewage flows. However, the fact that both urban surface runoff and domestic sewage overflows may make comparable and significant contri-

TABLE V-8

ANNUAL MASS DISCHARGES (lb/acre-yr)
FOR URBAN AREAS SIMILAR TO PILOT SECTORS

Constituent	Primary Effluent		Secondary Effluent**		Combined Sewer Overflows***		Separate+ Storm Sewer Discharges	
	Selby	Laguna	Selby	Laguna	Selby	Laguna	Selby	Laguna
BOD	1,450	4,050	175	554	101	136	25	29
COD	2,420*	6,750*	280	886	447	480	188	218
SS	1,415*	3,970*	105	332	632	538	570	~ 500
VSS	990	2,780	84	264	146	224	125	145
Grease	344	965	14	44	36	41	...	...
N	250*	792*	175	554	10.6	15.6	7.0	8.2
PO_4	262*	830*	210	664	2.4	3.2	2.0	2.3

*Assumptions:
- BOD:COD = 0.60
- VSS:SS = 0.70
- N = 35.7 mg/l
- PO_4 = 37.5 mg/l

**Assumed Concentrations:
- BOD 25 ppm
- SS 15 ppm
- Grease 2 ppm
- VSS 12 ppm
- COD 40 ppm
- N 25 ppm
- PO_4 30 ppm

Per capita flows
- Selby - 96 gcd
- Laguna - 107 gcd

+Calculated from Mass Discharge Factors from Cincinnati (see Table V-7) and annual runoff in the two pilot sectors in San Francisco.

***Without treatment

butions to receiving water pollution, further supports the argument against separate systems and suggests treatment as the more effective alternative.

Table V-8 has been prepared for purposes of comparing the relative mass discharges of sewage treatment plants, combined sewer overflows, and surface runoff in systems similar to those studied in this investigation. Certain of the figures were calculated based on assumptions which are indicated in the table. Generally, in the absence of secondary treatment, primary effluents constitute the bulk of mass discharges from urban areas, regardless of the constituent selected for comparison. For the constituents BOD, COD, VSS, and grease, the annual mass discharges from secondary effluents, combined sewer overflows, and separate storm sewer discharges are of the same order of magnitude. Quantities of suspended solids are notably higher in storm flows. Nutrients from dry weather sewage flows far overshadow those discharged from either combined or separate storm sewers.

Evaluation of Overflow Monitoring Results

There exists very little information with which to judge the universality of the data developed in this phase of the studies. The only other known comprehensive combined sewer overflow study was conducted in a small residential sector in Northampton, England by Gameson and Davidson (11). Figure V-23 contains a comparison of their BOD and suspended solids data with the information developed in this study for antecedent dry periods greater than one day.

The correspondence between two BOD-time relationships is excellent. The higher suspended solids results obtained in this study for time periods between 100 and 180 minutes are influenced by the data from a single storm, and should not be weighed too heavily. With this in mind, it can be stated with some assurance that the suspended solids relationships from the two studies are quite similar.

Palmer's data from Detroit (1) are compared in Table V-9 with the specific mass discharge factors obtained in this study.

TABLE V-9

COMPARISON OF MASS DISCHARGE FACTORS IN SAN FRANCISCO AND DETROIT

Constituent	Specific Mass Discharge Factor (lbs per acre-inch of runoff)		
	Detroit	Selby St. (S.F.)	Laguna St. (S.F.)
BOD	11.3	8.11	9.50
Suspended Solids	56.6	56.5	37.5
Volatile Suspended Solids	22.6	17.5	15.6
Coliform MPN*	4.3×10^4	$\sim 5 \times 10^4$	$\sim 5 \times 10^4$

* Organisms per ml

The data from Detroit, although obtained in a limited study, agree well with the San Francisco data.

On this basis it can be concluded that combined sewer overflows from principally residential urban areas are adequately described by the relationships illustrated in Figures V-15 to V-20. The principal reason for the homologous quality characteristics of combined sewer overflows from areas of dissimilar topography is undoubtedly related to the debris washed from roofs, lawns, walks, and streets. That is, surface runoff controls the quality patterns in the overflows. If storage in the sewerage system were a significant factor, then it would be expected that the Laguna Street specific mass discharge factors would be much less than those determined at Selby Street. However, the sewer slopes in the Laguna Street system are in general exceedingly steep, and the resultant high velocities would tend to inhibit deposition from dry weather flows. As the specific mass discharge factors for the two sectors are quite similar, it must be assumed that in-system storage did not contribute significantly to the mass of materials discharged in the two pilot areas studied. However, it is possible that in certain urban areas with flat sewer slopes, debris storage may be a significant factor.

RECEIVING WATER STUDIES

In Figure IV-10 the sampling stations selected for receiving water studies in the Laguna outfall area were shown. The monitoring for background coliform levels was carried out on 20 Dec. 1966 and 17 Jan. 1967. No rainfall occurred between 9 December 1966 and 20 January 1967; consequently, a minimum of two weeks of dry weather preceded each sampling period. Tables V-10 and V-11 include both total and fecal coliform MPN's from the two days of dry weather monitoring. For reference purposes, the tidal data from Golden Gate Bridge (approximately two miles away) are listed in Table V-12.

TABLE V-12

TIDAL DATA, GOLDEN GATE BRIDGE

Date	Time	Tide (ft)	Date	Time	Tide (ft)
19 Dec 66	2306	1.0	16 Jan 67	2118	1.0
20 Dec 66	0624	5.2	17 Jan 67	0436	5.1
	1242	2.2		1048	2.2
	1812	3.6		1618	3.7
	2354	1.4		2200	1.5
21 Dec 66	0700	5.4	18 Jan 67	0506	5.2
				1148	1.8

Analysis of the dry weather background coliform data lead to the following conclusions:

TABLE V-10

LAGUNA STREET
DRY WEATHER RECEIVING WATER COLIFORM MPN'S

20 December 1966

Results expressed as Total Coliforms/Fecal Coliforms per ml

Sample	Time	STATION 1*	2*	3*	4	5	6+	7+
1	0948	70/2.3	6.2/2.3	6.2/2.3	24/0.46	2.3/0.6	6.2/6.2	24/6.2
2	1123	24/2.3	24/6.2	2.3/0.6	2.3/0.6	24/2.3	2.3/0.6	24/2.3
3	1534	2.3/2.3	24/2.3	2.3/2.3	6.2/1.3	24/0.6	6.2/2.3	6.2/6.2
4	1805	6.2/2.3	24/2.3	2.3/2.3	24/2.3	24/0.46	70/2.3	24/2.3
5	2205	6.2/2.3	6.2/0.6	6.2/0.46	6.2/2.3	2.3/2.3	6.2/2.3	24/24
6	0030	70/1.3	24/6.2	24/2.3	24/<0.46	2.3/0.6	70/24	24/2.3
7	0320	>70/24	24/0.6	70/1.3	24/24	6.2/0.6	6.2/2.3	70/13
8	0620	24/6.2	70/0.6	24/2.3	24/2.3	6.2/2.3	24/24	2.3/0.6

*Sampling stations nearest outfall.
+Sampling stations outside Marina harbor.

TABLE V-11

LAGUNA STREET

17 January 1967

DRY WEATHER RECEIVING WATER COLIFORM MPN'S

Results expressed as Total Coliforms/Fecal Coliforms per ml

Sample	Time	STATION 1*	2*	3*	4	5	6+	7+
1	0653	70 / 1.3	6.2 / 0.6	24 / 6.2	24 / 6.2	2.3 / 0.6	2.3 / 2.3	6.2 / 6.2
2	0938	1.3 / 0.6	6.2 / < 0.6	2.3 / 0.6	6.2 / 0.6	6.2 / <0.6	0.6 / 0.6	< 0.6 / < 0.6
3	1230	6.2 / 0.46	2.3 / 0.6	2.3 / 0.6	0.6 / 0.6	2.3 / < 0.6	2.3 / < 0.6	2.3 / 0.6
4	1530	6.2 / < 0.6	1.3/6.2 / < 0.6	0.6 / 0.6	2.3 / < 0.6	0.6 / < 0.6	2.3 / < 0.6	2.3 / < 0.6
5	1825	2.3 / < 0.6	2.3 / < 0.6	6.2 / 0.6	0.6 / < 0.6	0.6 / 0.6	6.2 / < 0.6	0.6 / 0.6
6	2123	0.6 / < 0.6	1.2 / < 0.6	2.3 / < 0.6	24 / 0.6	< 0.6 / < 0.6	6.2 / 2.3	6.2 / 0.6
7	0030	2.3 / < 0.6	2.3 / 0.6	6.2 / 2.3	6.2 / 0.6	2.3 / < 0.6	24 / 1.3	6.2 / < 0.6
8	0325	6.2 / 2.3	2.3 / 2.3	2.3 / 0.6	2.3 / <0.6	6.2 / 0.6	6.2 / 0.6	6.2 / < 0.6

*Sampling stations nearest outfall.

+Sampling stations outside Marina harbor.

1. Coliform MPN's on 17 January were significantly less than on 20 December. On the latter date only three samples showed a total coliform MPN greater than 10 per ml.

2. The ratio of total to fecal coliforms was about the same as in the trunk sewer, i.e., approximately 10:1.

3. Comparison of the two days' data showed no consistent relationship between tide and coliform density for six of the seven stations.

Wet weather monitoring of overflow from the Laguna Street outfall was conducted on 10 March 1967 and 15 March 1967, and receiving water monitoring was carried out from 10 March 1967 to 19 March 1967 with two samples per day per station. Although the overflows were sampled only on 10 and 15 March, rainfall occurred almost continuously between the two dates, as shown in Figures V-24 through V-27.

The receiving water confirmed and fecal coliform MPN's are plotted in Figures V-24 through V-27, and Appendix F contains the numerical data. For plotting purposes the stations have been divided into two sets; those which are within the limits of the harbor, and those which are adjacent to or in the bay (Station 4 appears in both sets). Because of the limited number of dilutions used for each sample, in some instances all tubes were positive whereas on other occasions no positive tubes were encountered. Such results are indicated in Figures V-24 to V-27 by arrows which signify either higher or lower MPN's than actually plotted.

The high coliform levels detected in the Marina were not unexpected as the body of water is relatively confined. With an average coliform MPN of 5×10^4 per ml, combined sewer overflows create an overwhelming impact in areas where dilution is restricted. On the other hand, the data indicate an extremely rapid decrease in coliform levels at the termination of rainfall. For many of the stations the time for a 90 percent decrease, or t_{90}, was in the range of one-half day. It is also somewhat apparent that following periods of discharge, the residual coliform levels are higher than normally encountered in dry weather. It will be recalled that the data collected after six weeks of dry weather indicated significantly lower MPN's than the information obtained after only two weeks without precipitation.

As in previous phases of the study, the 10:1 ratio of total to fecal coliforms was generally found to occur. Because of the significance of these organisms in the regulation of water quality, the basis for this proportionality should receive further attention.

The receiving water studies have emphasized the previously recognized fact that in order to maintain recreational level of bacteriological water quality in the environment of combined sewer outfalls, it will be essential that some means of disinfection of overflows be employed.

DISSOLVED AIR FLOTATION EXPERIMENTS

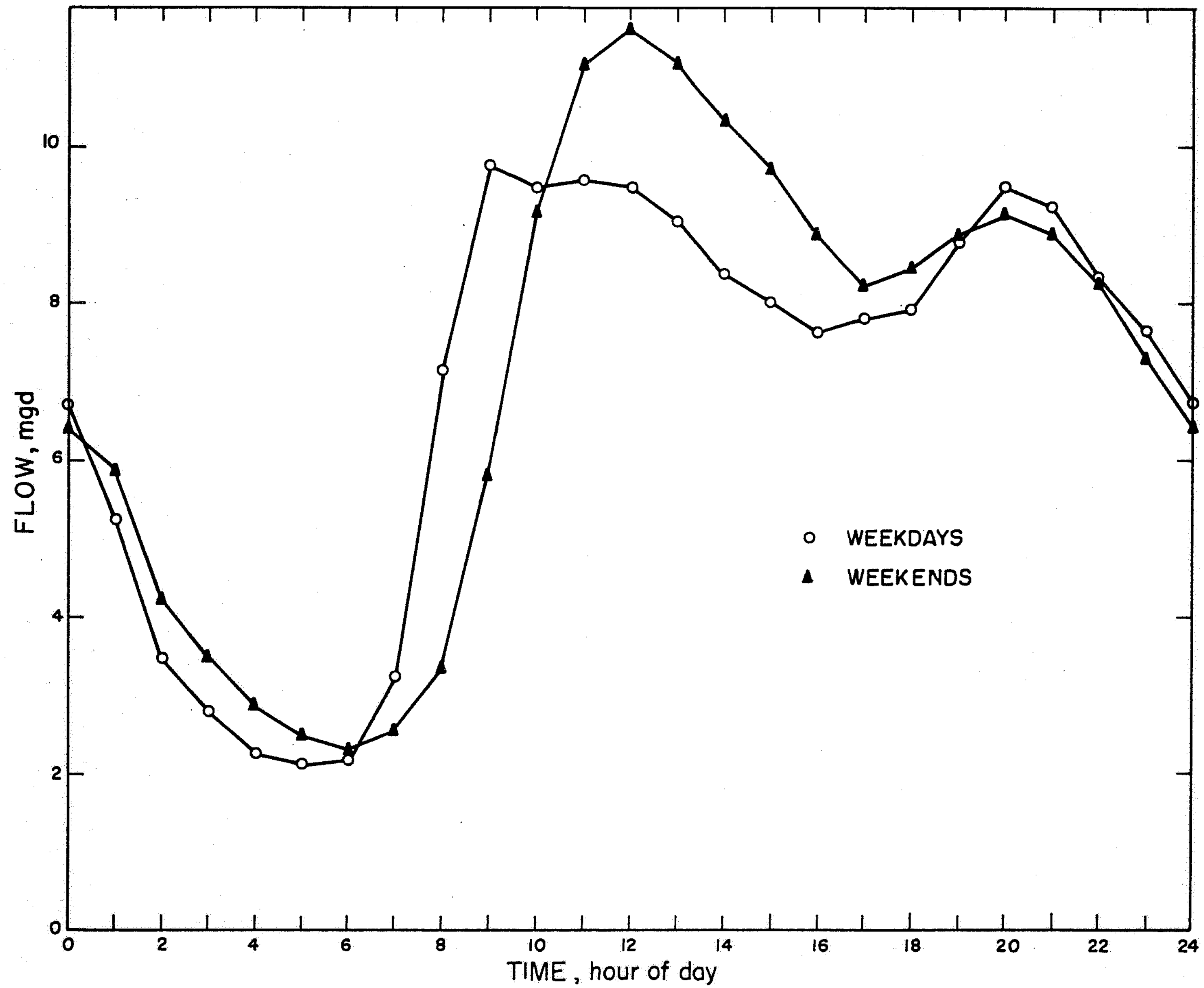
Samples from the overflows of 24 February 1967 at Selby Street and 10 March 1967 at Laguna Street were subjected to dissolved air flotation experiments. Aliquots were removed from the apparatus at selected intervals and analyzed for grease and COD. Figures V-28 through V-32 depict the results of the laboratory experiments.

Theoretically the relationship of time in the laboratory apparatus to surface loading rate is as follows:

Surface Loading Rate (gsfd)	Time in Laboratory Test Apparatus (sec)
5,000	94
10,000	47
20,000	24

The laboratory experiments clearly demonstrated that dissolved air flotation is a potentially feasible method for the treatment of combined sewer overflows. In addition to excellent removals of grease, the process is capable of effecting significant reductions of other pollutional materials as demonstrated by the COD results. The experiments show that surface loading rates in the range of 5,000 gsfd might be practical from a design standpoint and that recycle ratios of 10 to 20 percent are probably sufficient to achieve 80 percent grease removal.

The selective removal of floatable materials by dissolved air flotation makes this process particularly attractive for combined sewer overflow treatment, since floatables create the most offensive aesthetic problems in receiving waters. The high surface loading rates attainable are also a definite attribute of the process, as areal requirements are reduced with increasing surface loading rates. This factor can be extremely important in high density urban areas.



DIURNAL DRY WEATHER FLOW VARIATIONS
SELBY STREET

FIGURE V-1

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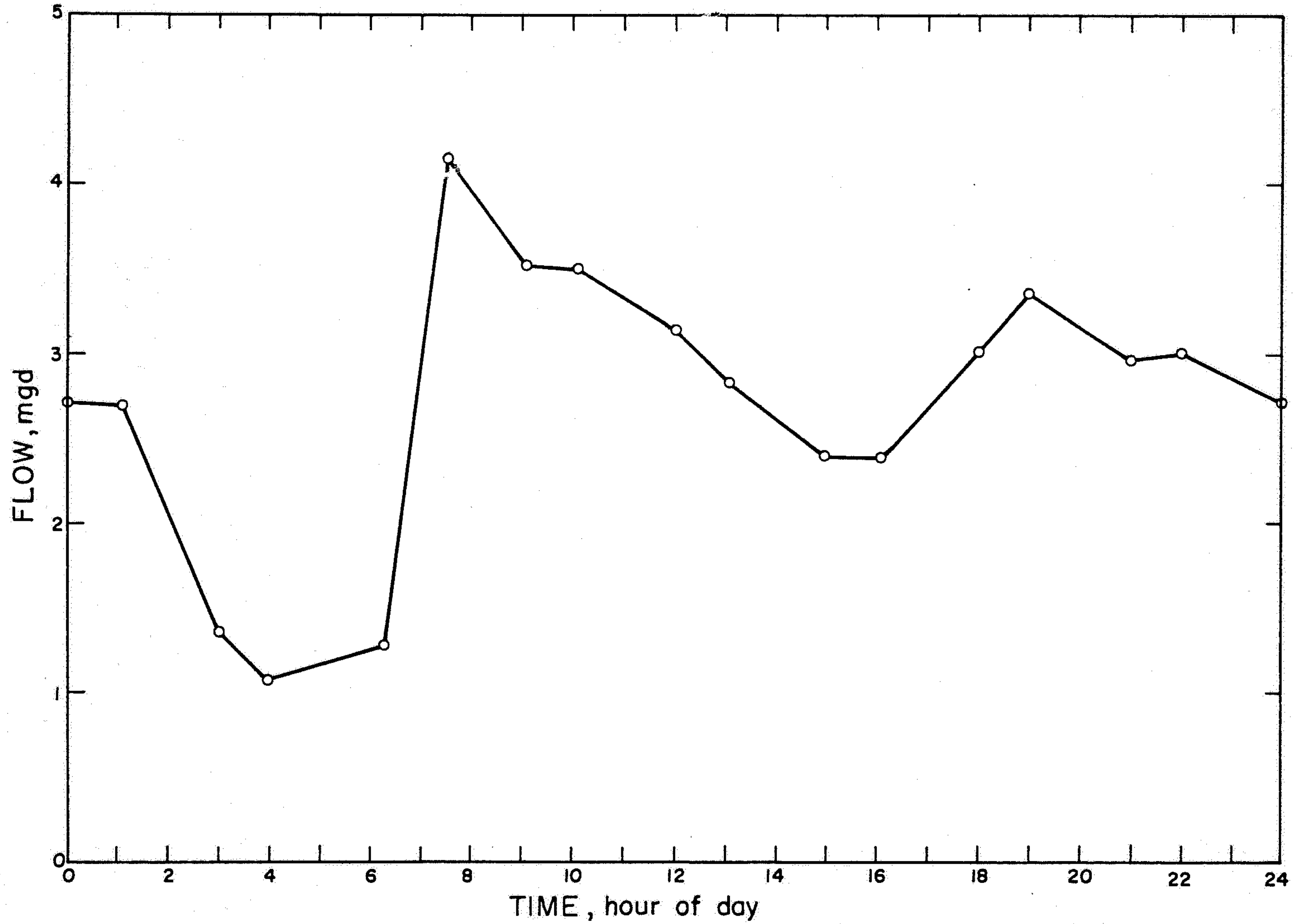

DIURNAL DRY WEATHER FLOW VARIATIONS
LAGUNA STREET

FIGURE VI - 2

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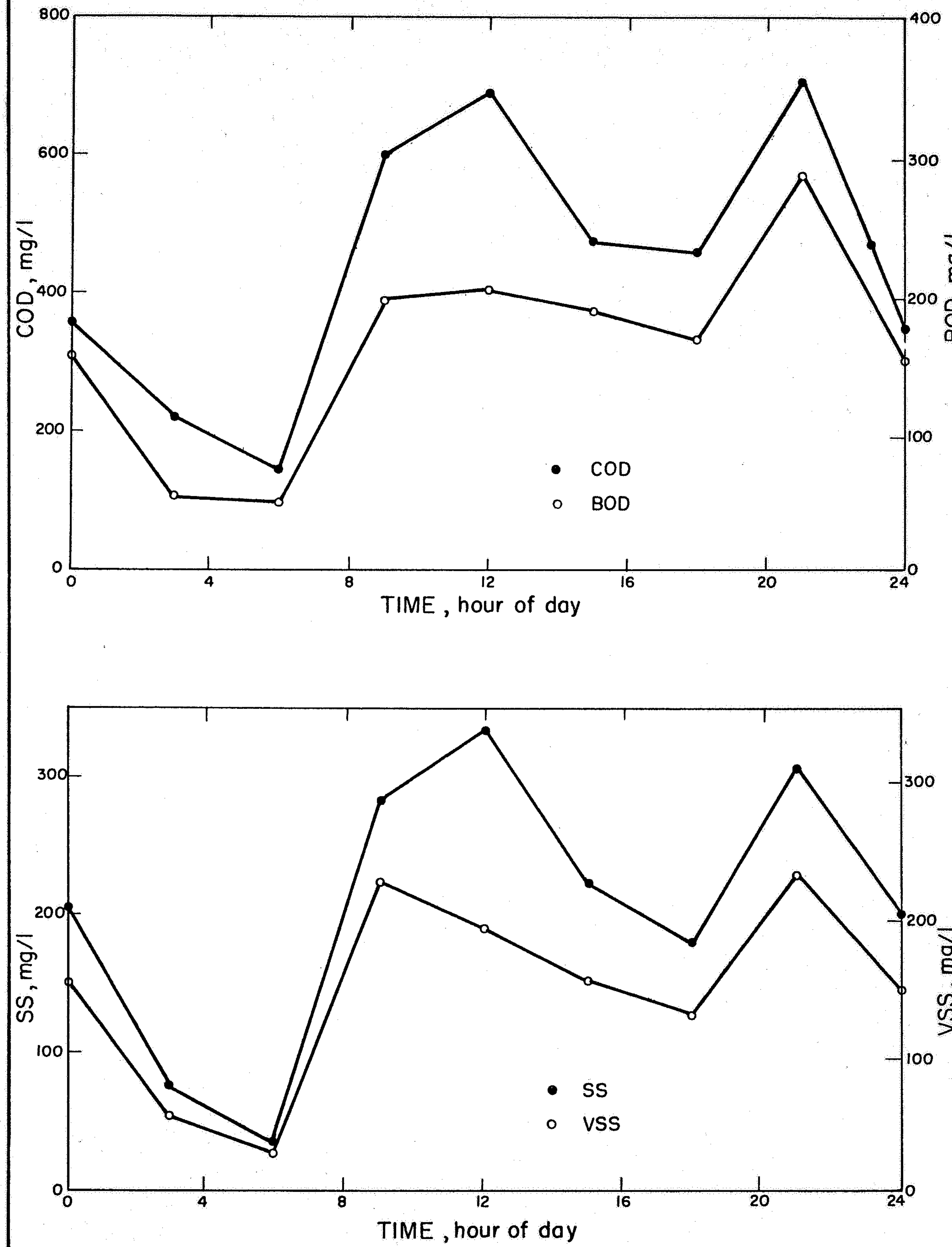
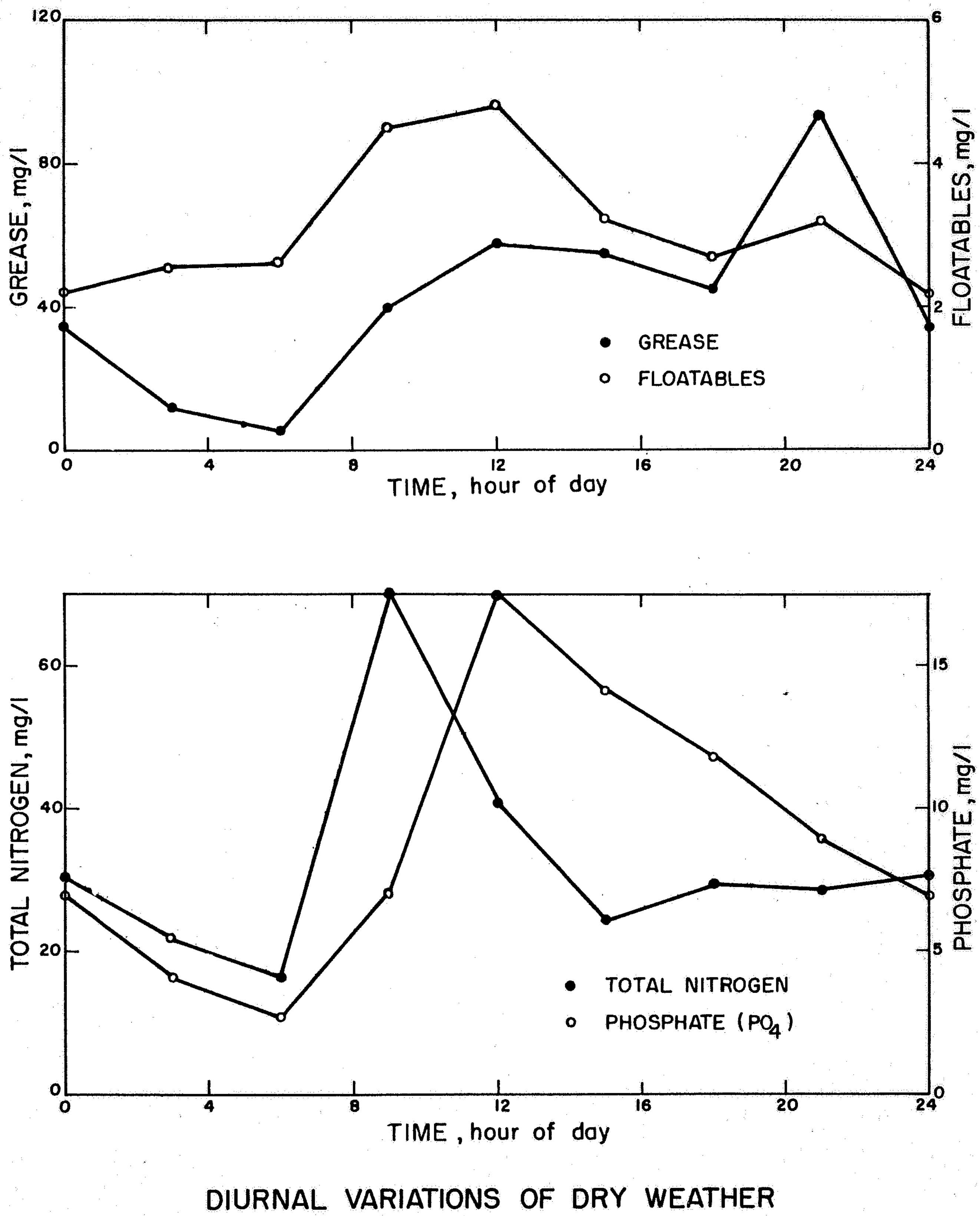
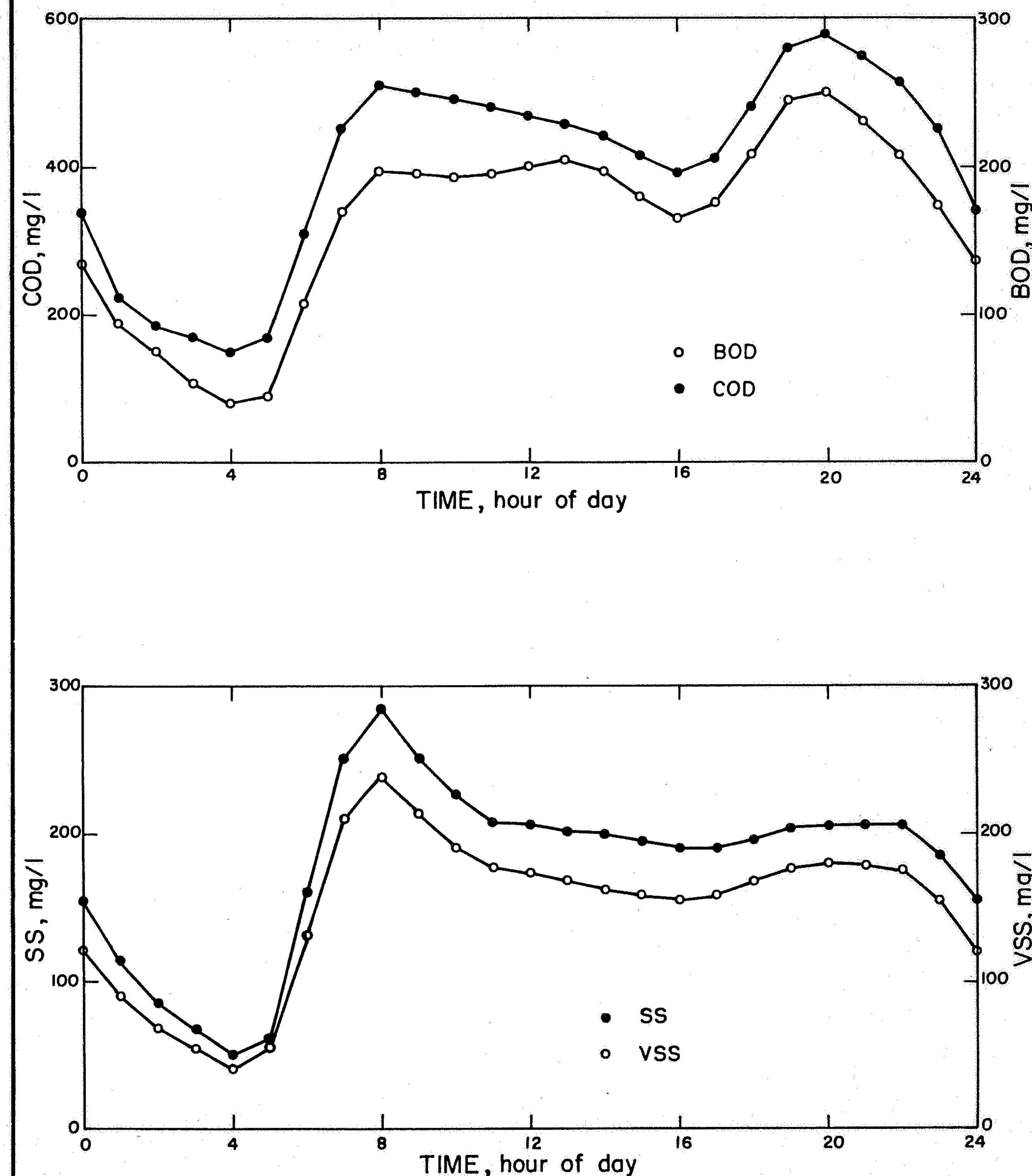


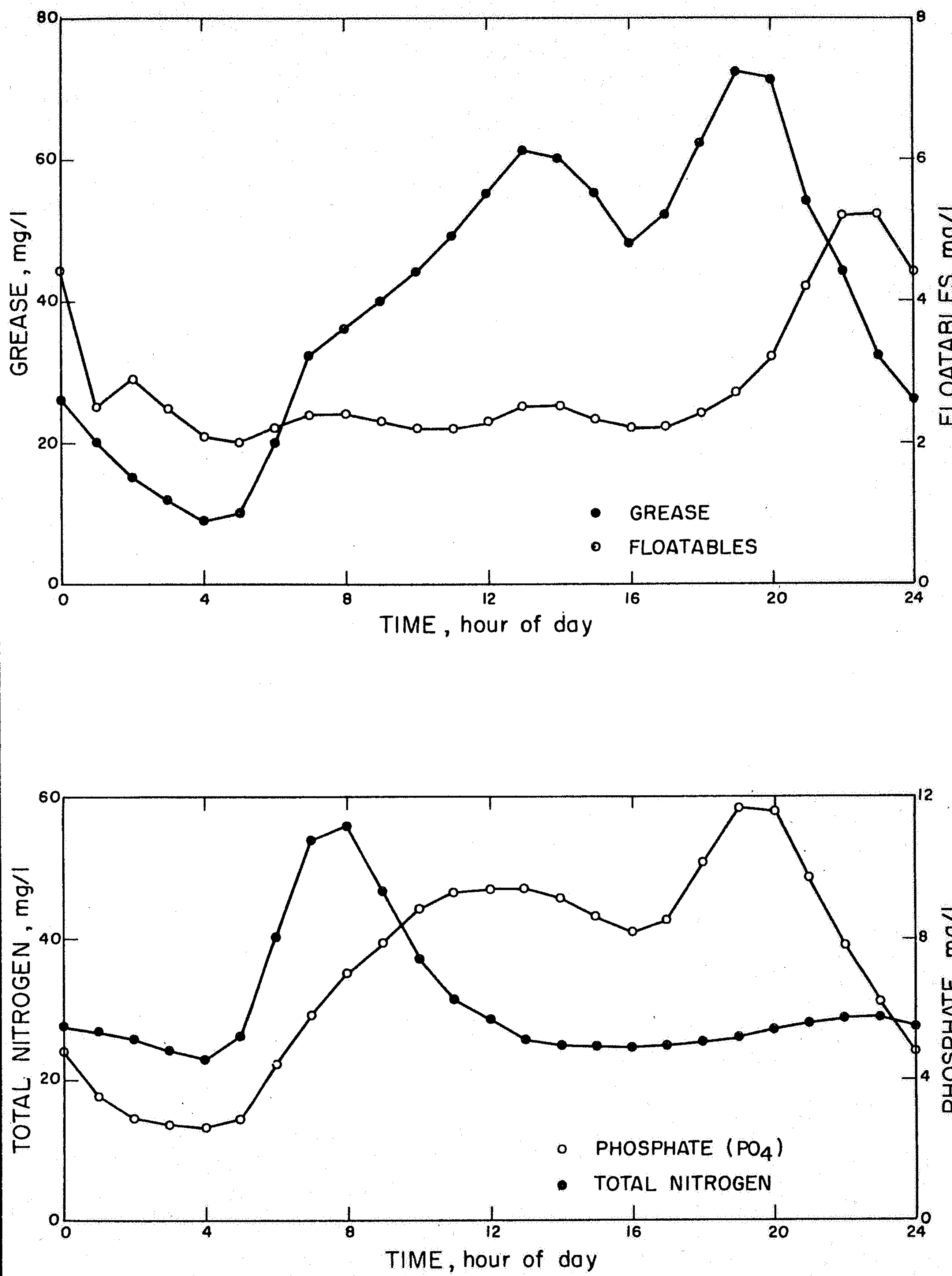
DIURNAL VARIATIONS OF DRY WEATHER SEWAGE CHARACTERISTICS - SELBY STREET



DIURNAL VARIATIONS OF DRY WEATHER SEWAGE CHARACTERISTICS - SELBY STREET



DIURNAL VARIATIONS OF DRY WEATHER
SEWAGE CHARACTERISTICS - LAGUNA STREET



DIURNAL VARIATIONS OF DRY WEATHER SEWAGE CHARACTERISTICS - LAGUNA STREET

DIURNAL COLIFORM VARIATIONS
SELBY STREET SEWER

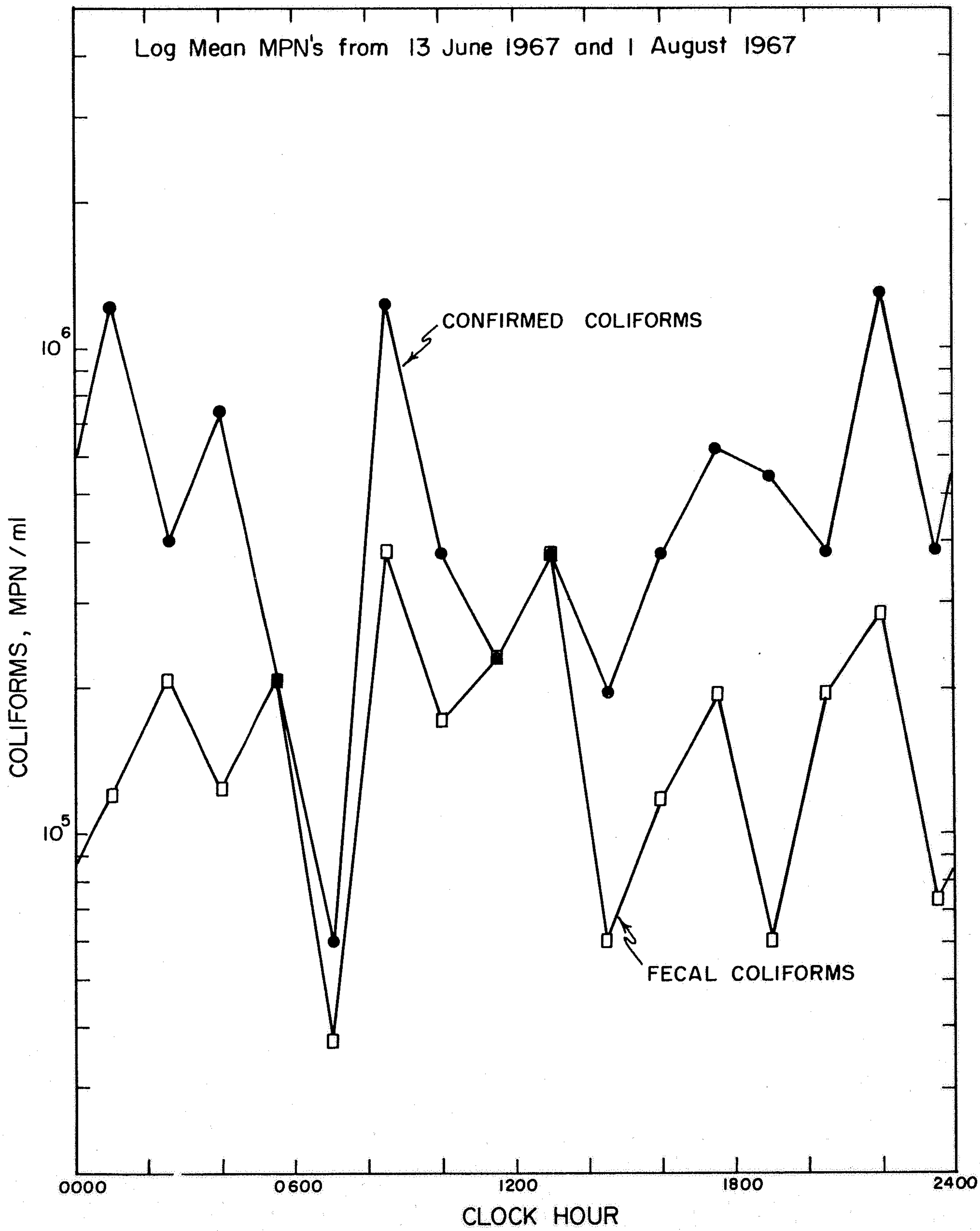
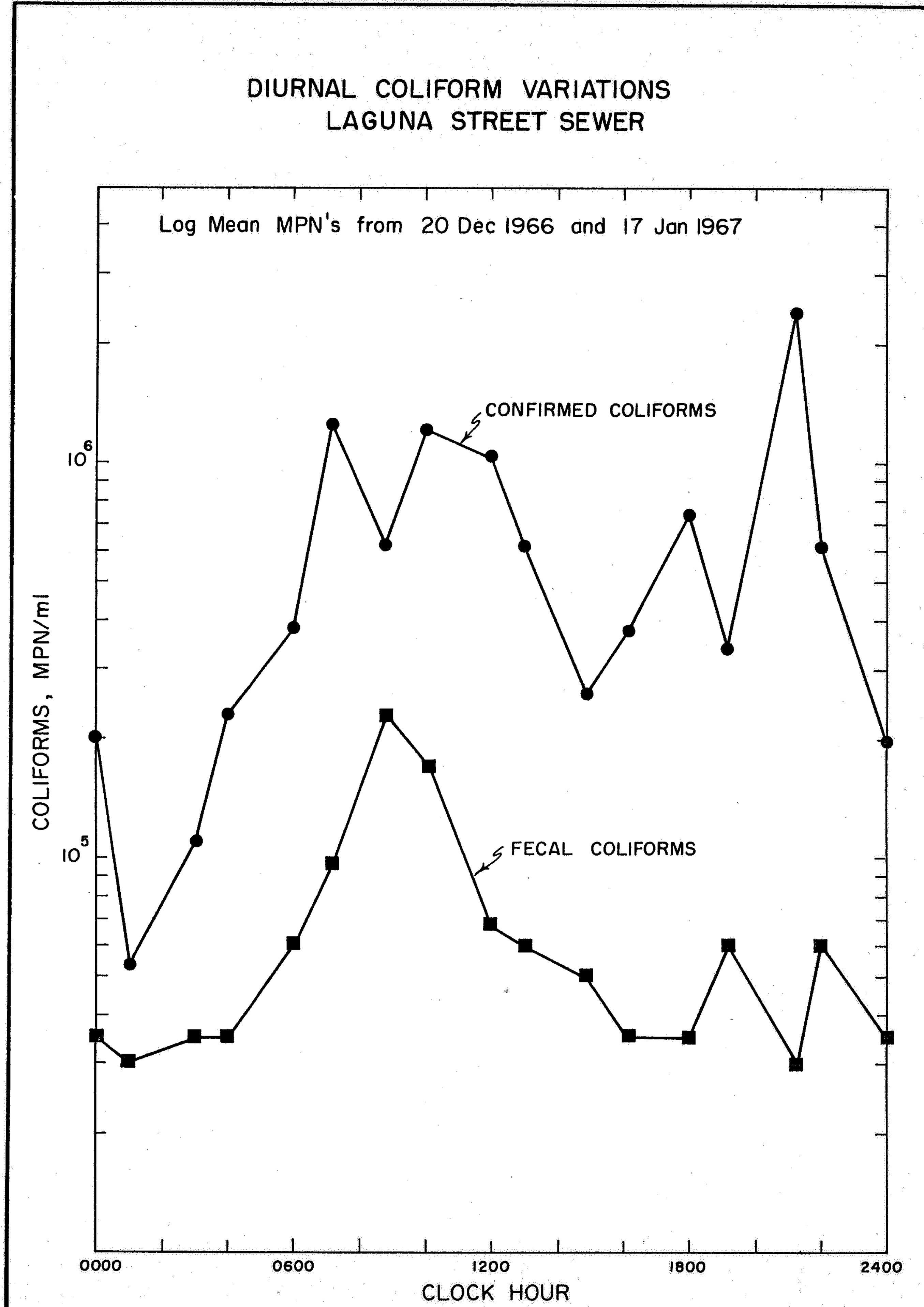


FIGURE V-8



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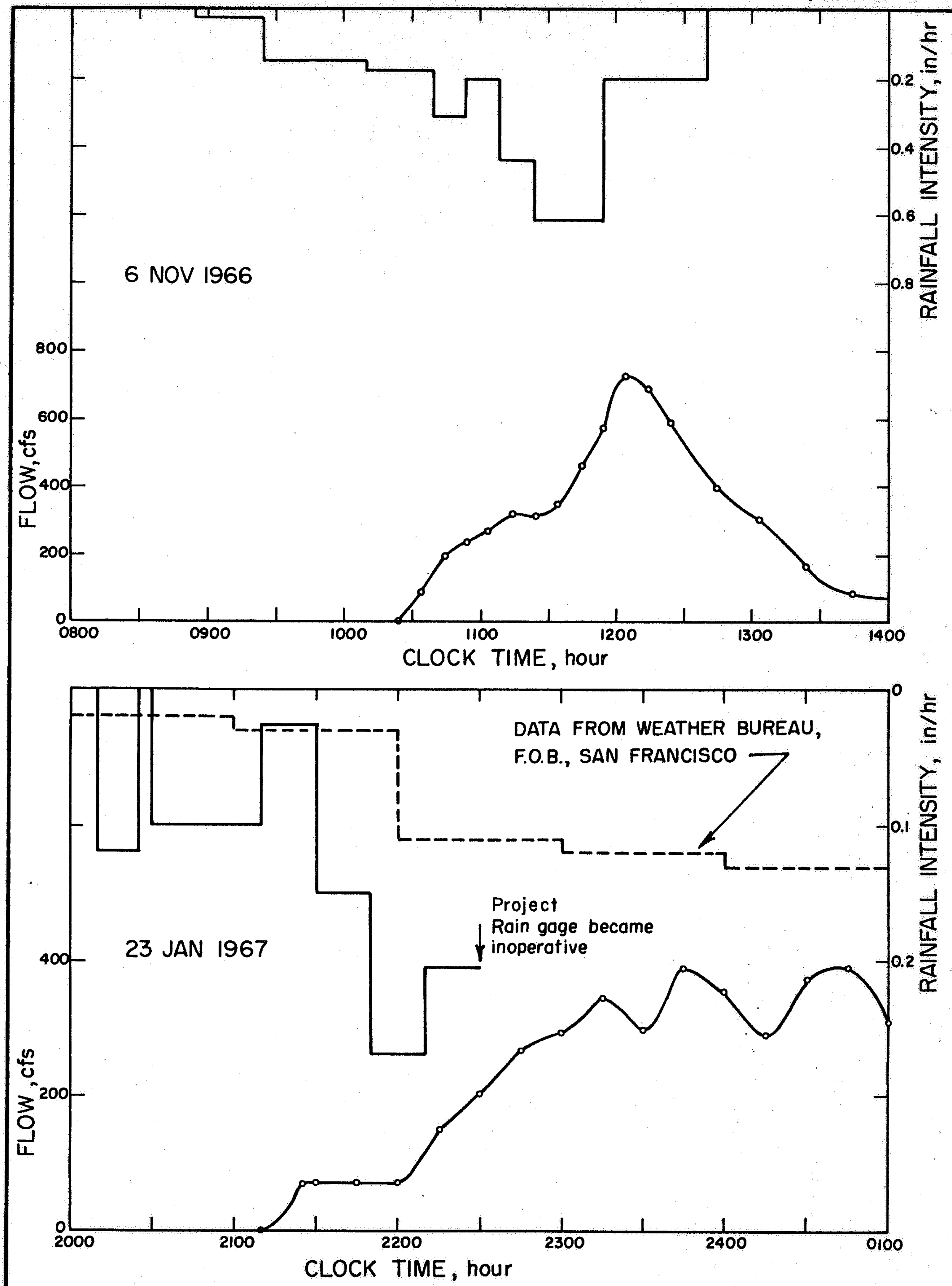
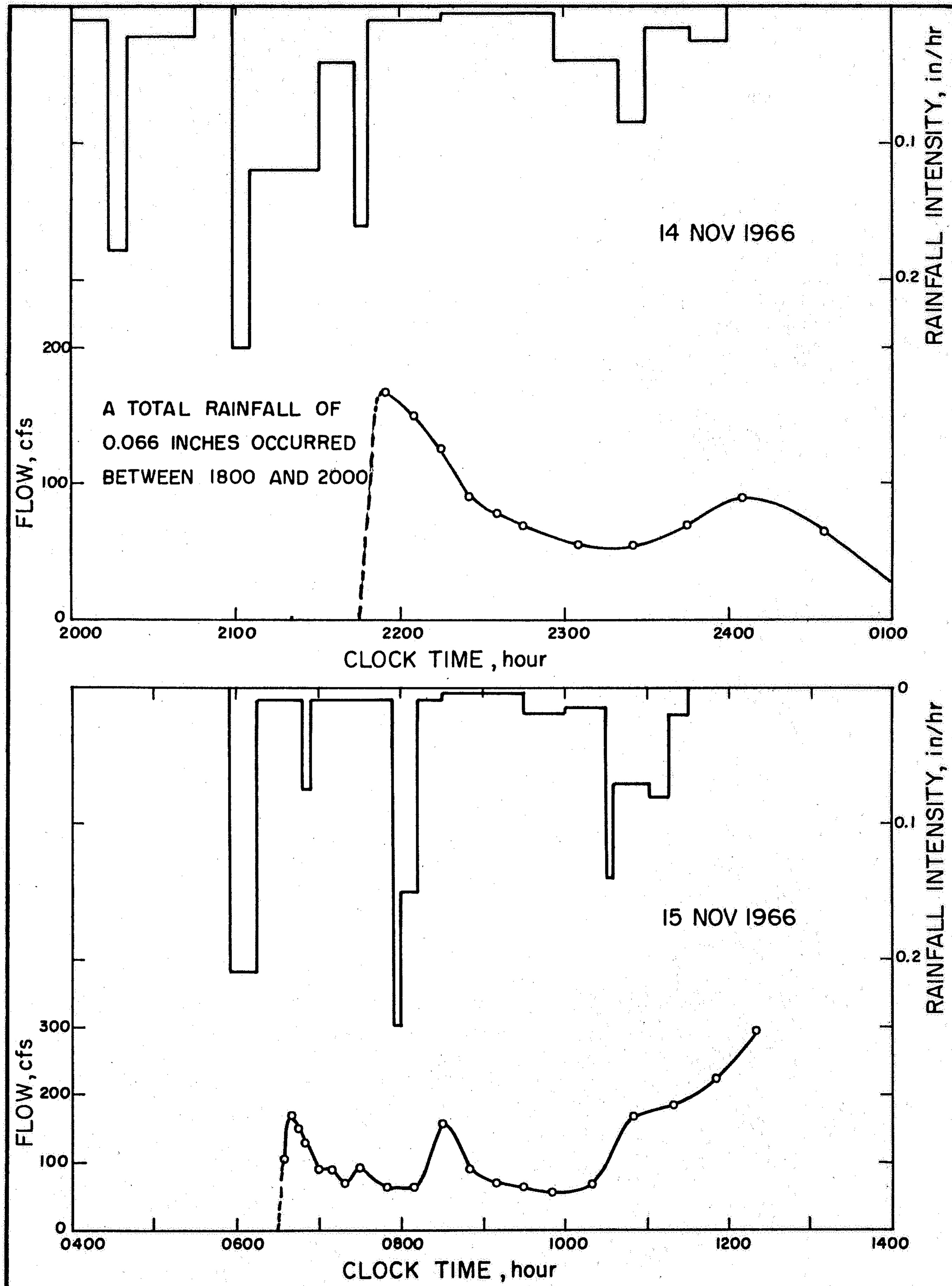
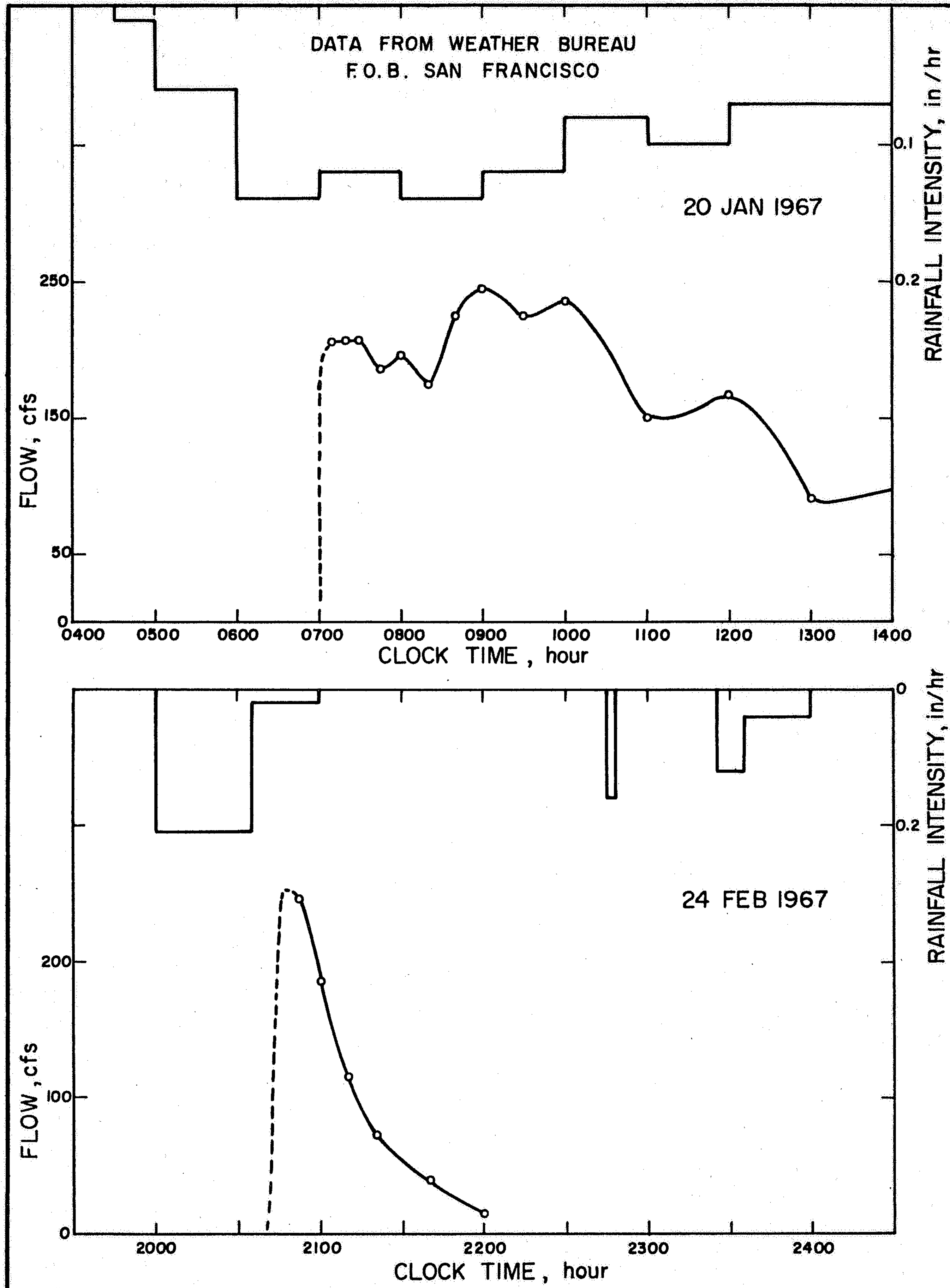


RAINFALL INTENSITY AND RATE OF DISCHARGE
SELBY STREET OUTFALL

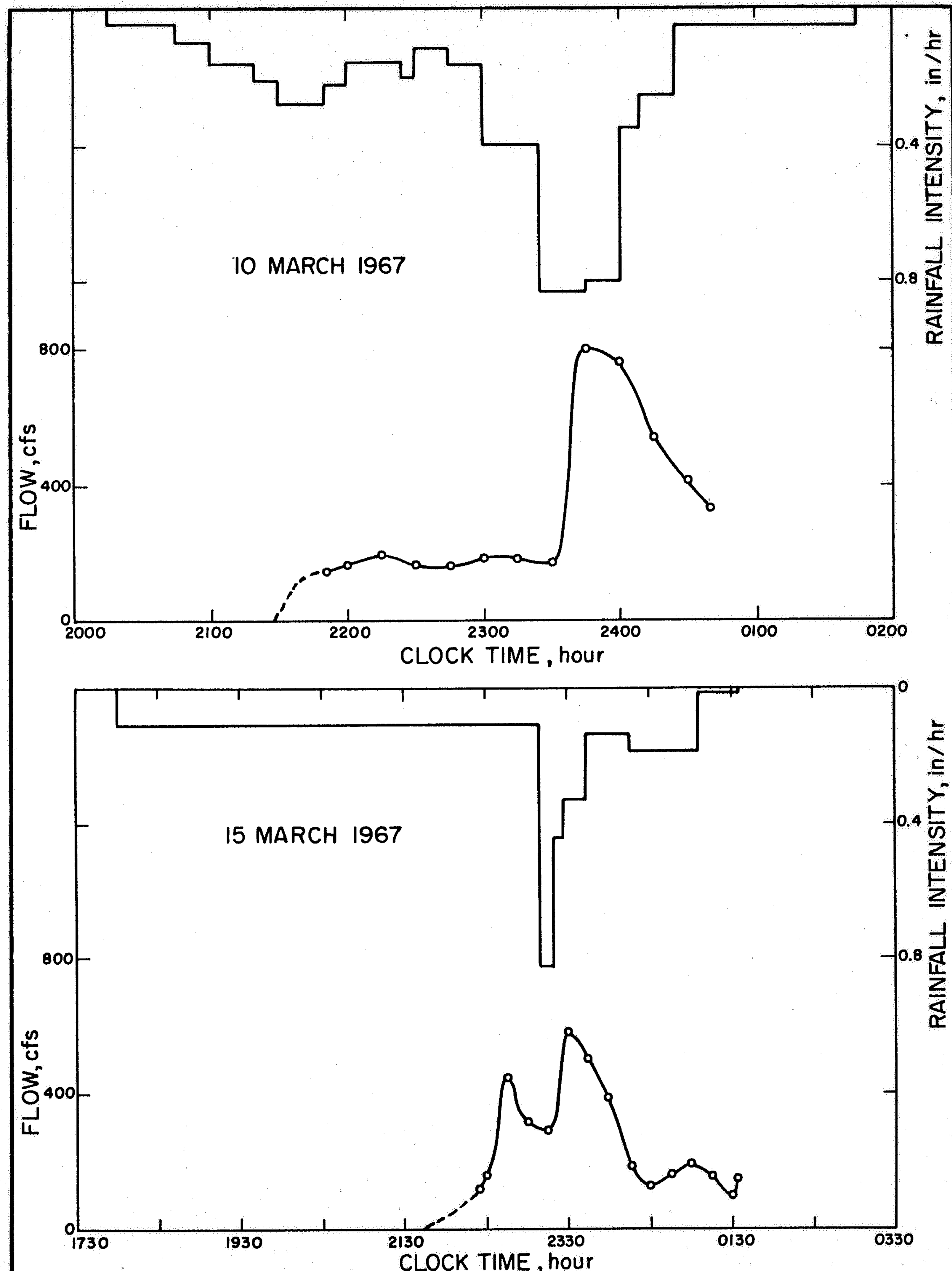
FIGURE V - 10



RAINFALL INTENSITY AND RATE OF DISCHARGE
SELBY STREET OUTFALL

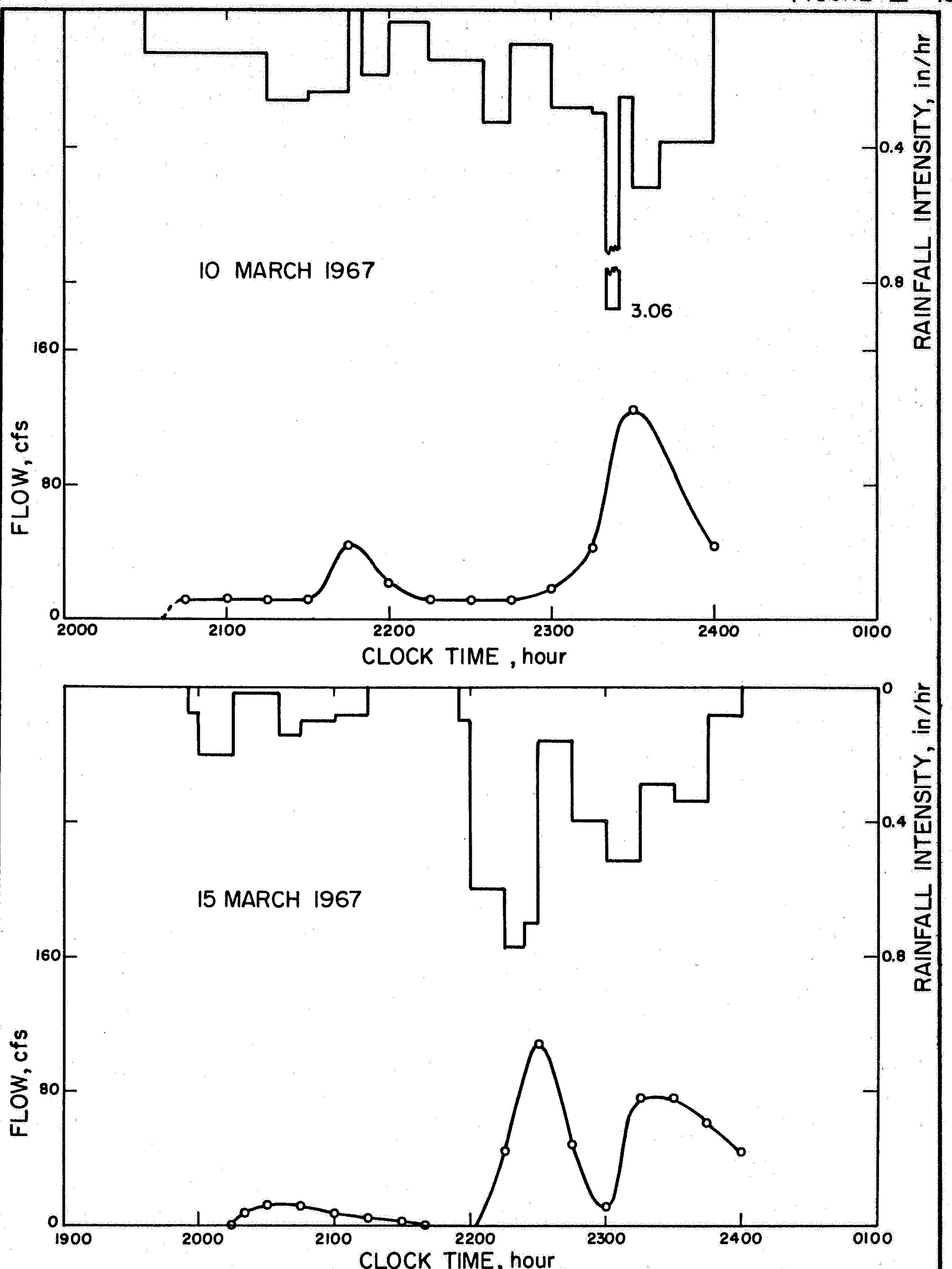


RAINFALL INTENSITY AND RATE OF DISCHARGE
SELBY STREET OUTFALL



RAINFALL INTENSITY AND RATE OF DISCHARGE
SELBY STREET OUTFALL

FIGURE V - 13



RAINFALL INTENSITY AND RATE OF DISCHARGE
LAGUNA STREET OUTFALL

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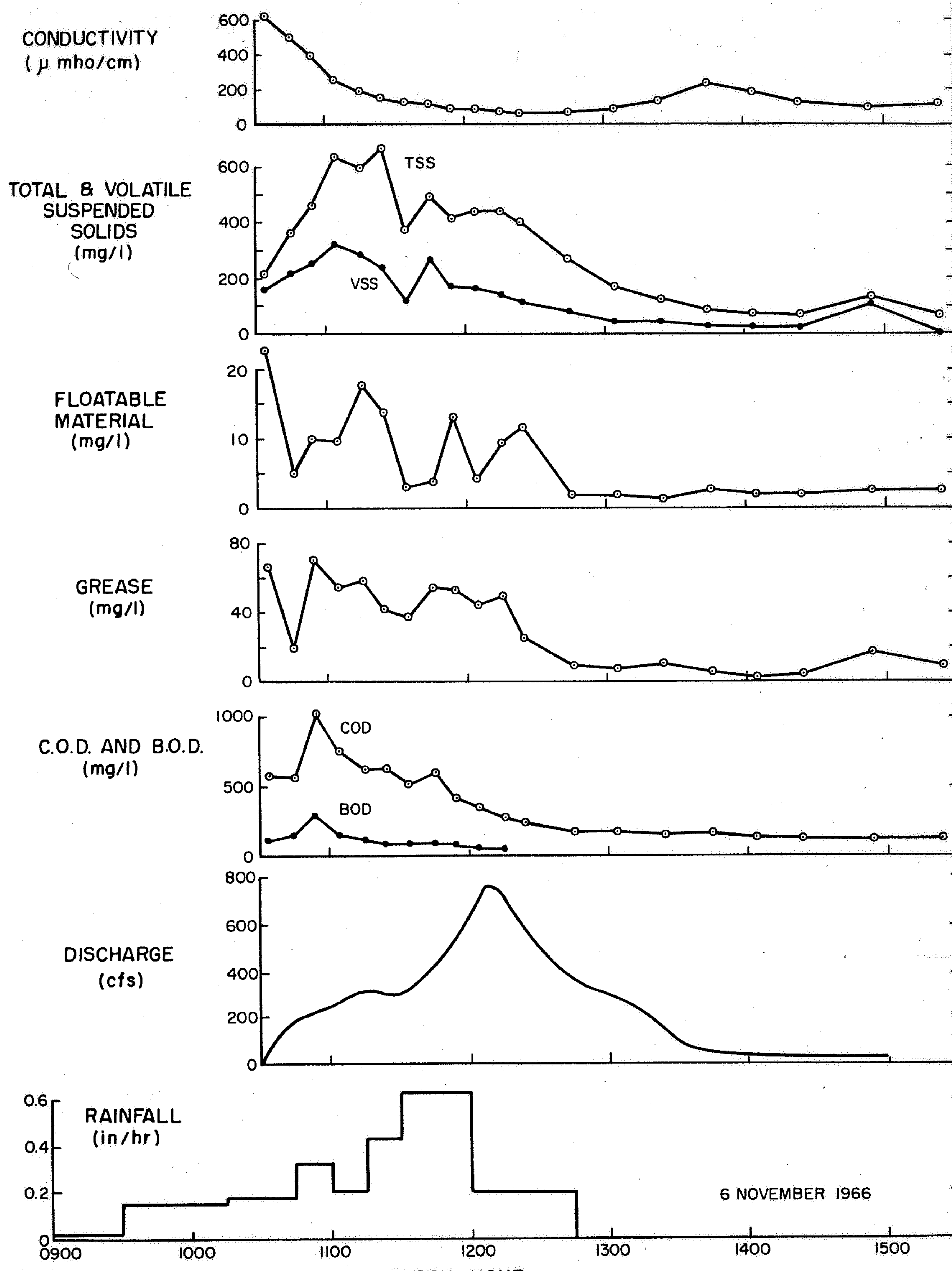
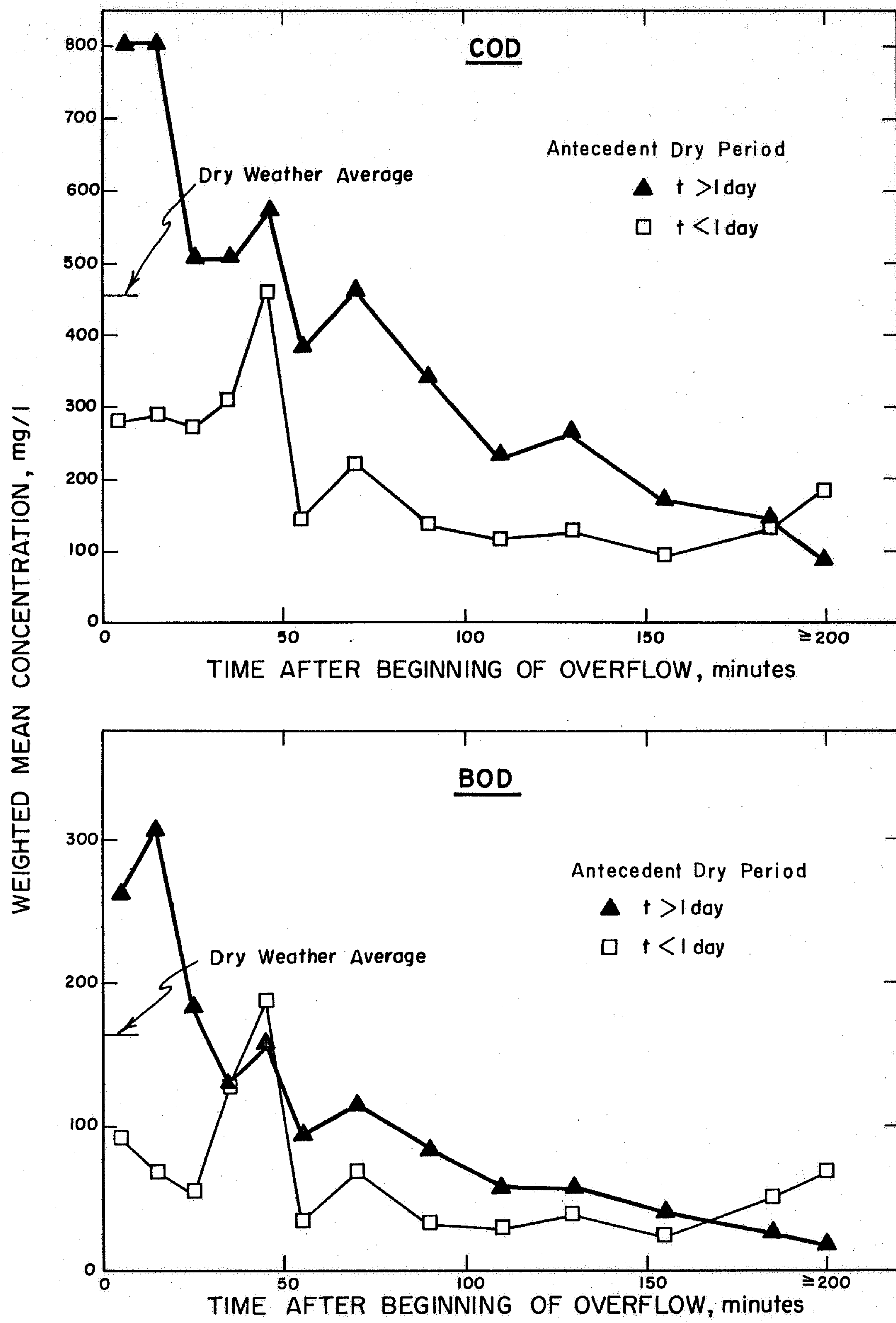


CHARACTERISTICS OF RAINFALL AND COMBINED SEWER OVERFLOW, SELBY STREET



CONSTITUENT CONCENTRATION VARIATIONS IN COMBINED SEWER OVERFLOW - SELBY STREET

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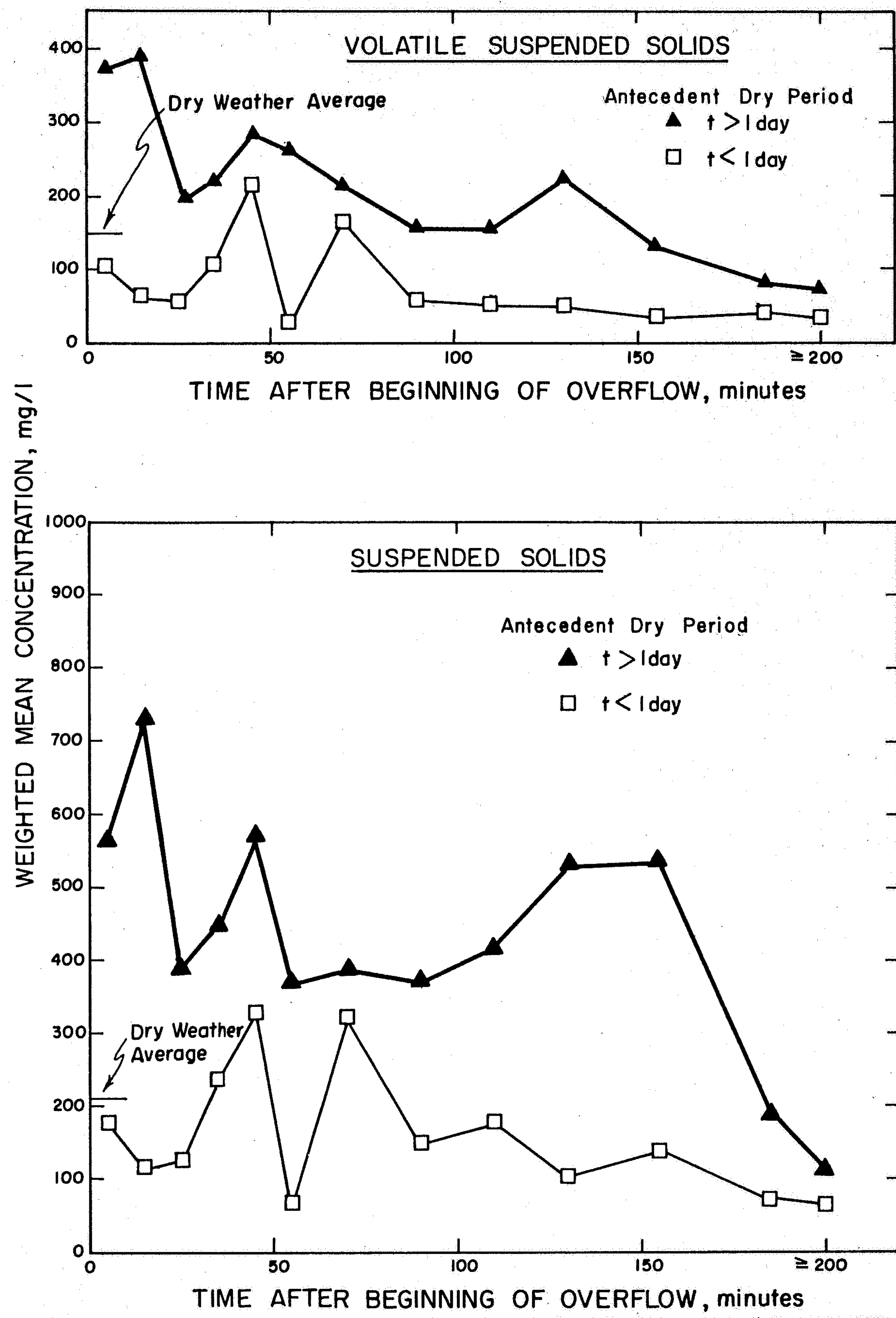
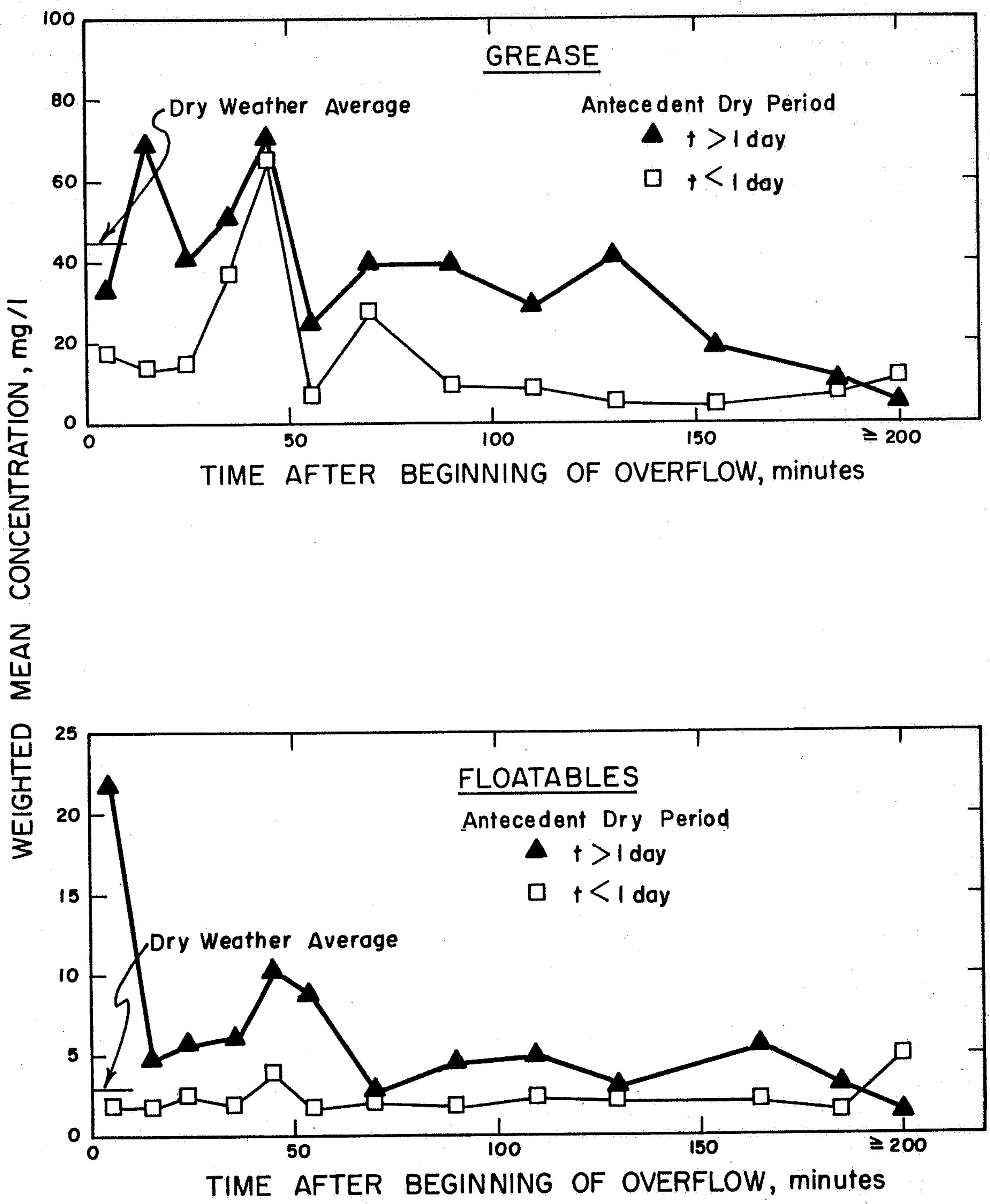


CONSTITUENT CONCENTRATION VARIATIONS IN COMBINED SEWER OVERFLOWS - SELBY STREET



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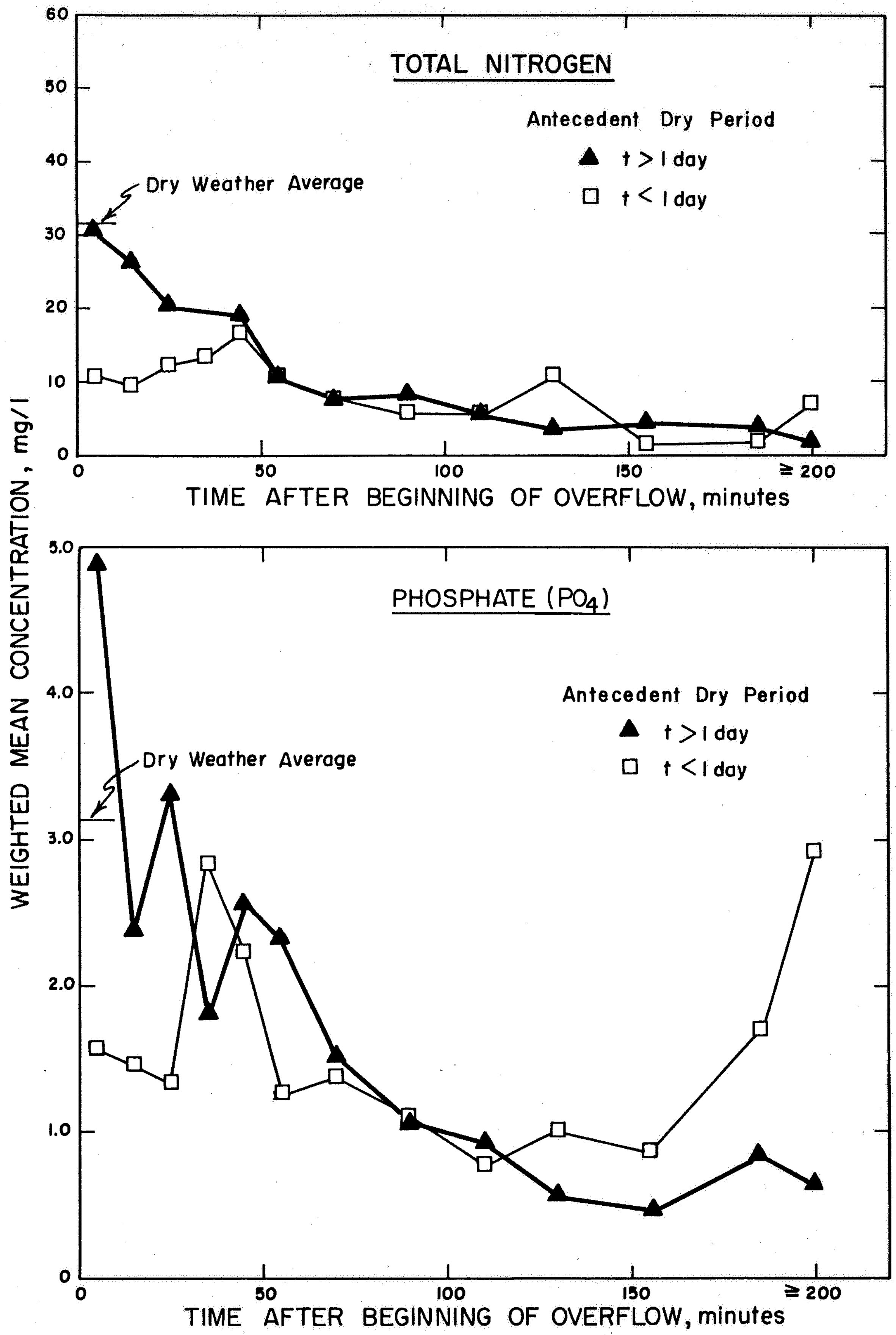

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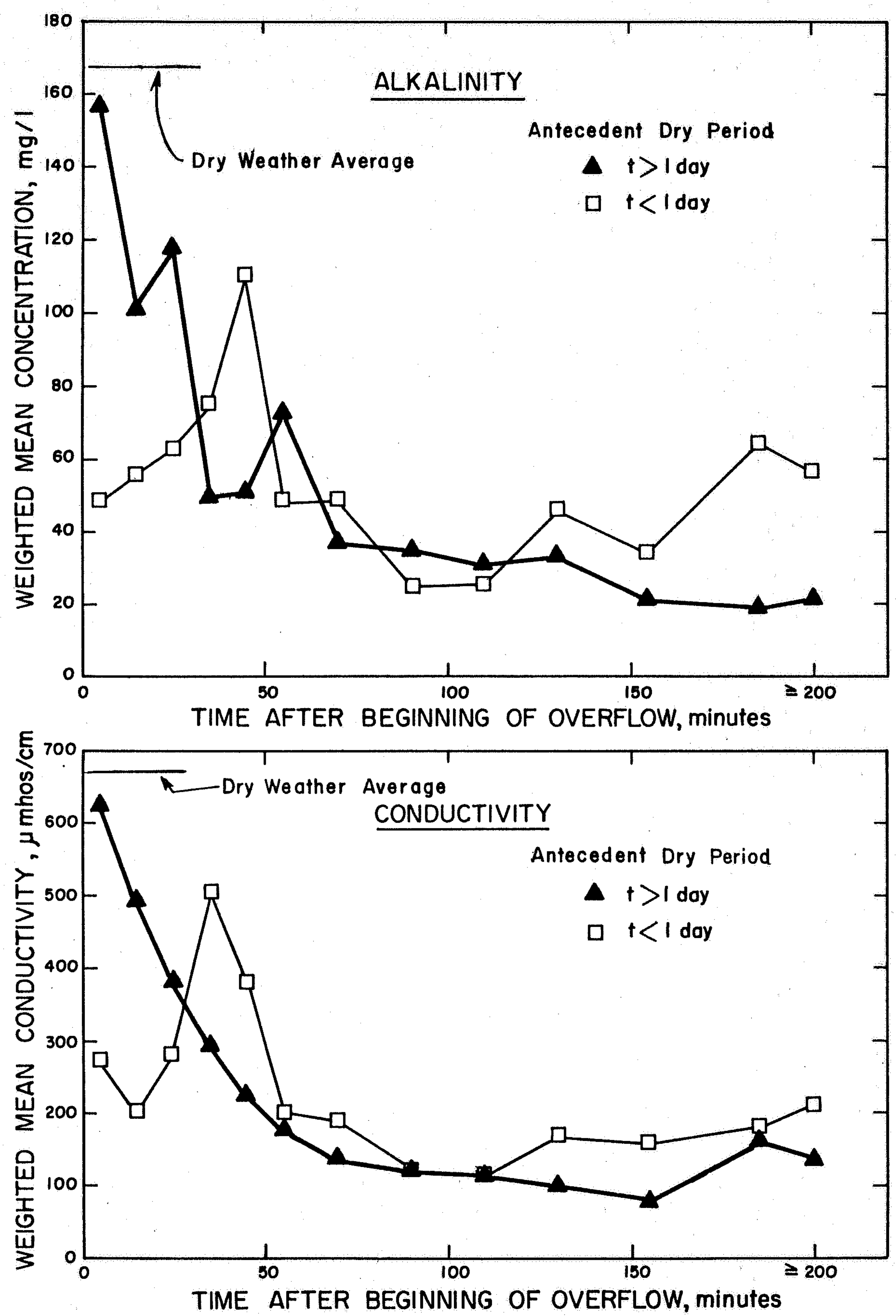

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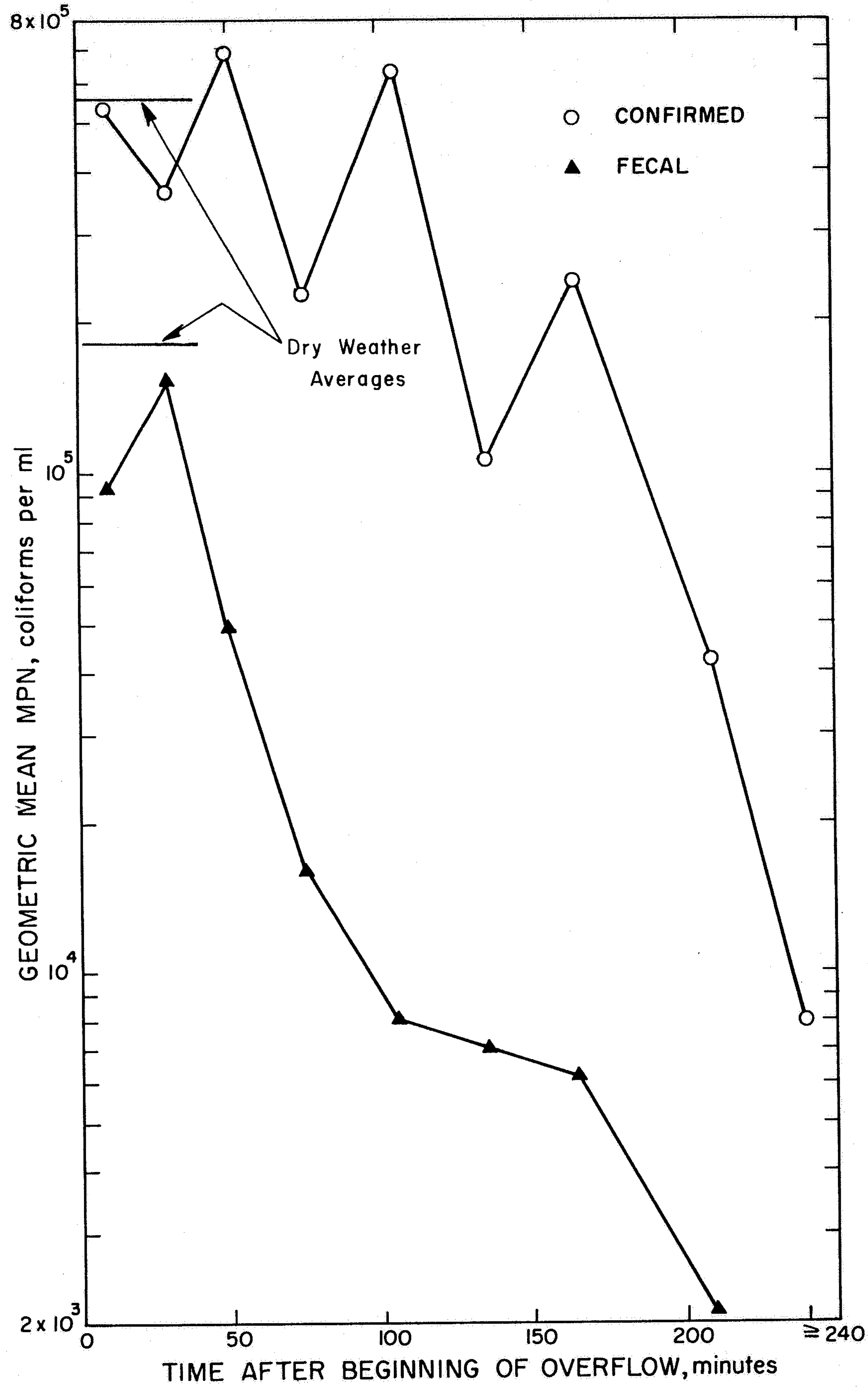
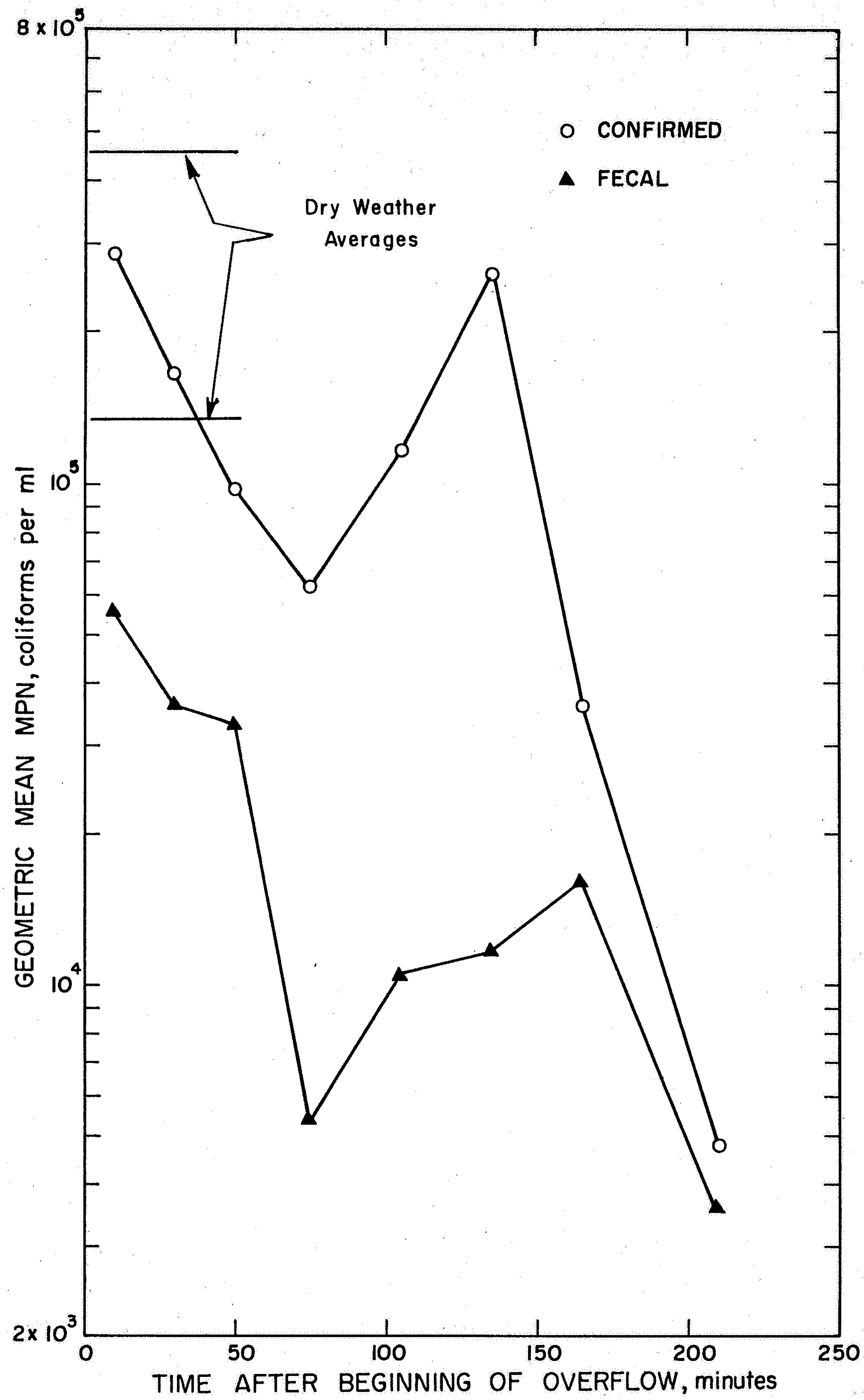


COLIFORM MPN VARIATIONS IN COMBINED SEWER OVERFLOWS - SELBY STREET



COLIFORM MPN VARIATIONS IN COMBINED SEWER OVERFLOWS – LAGUNA STREET

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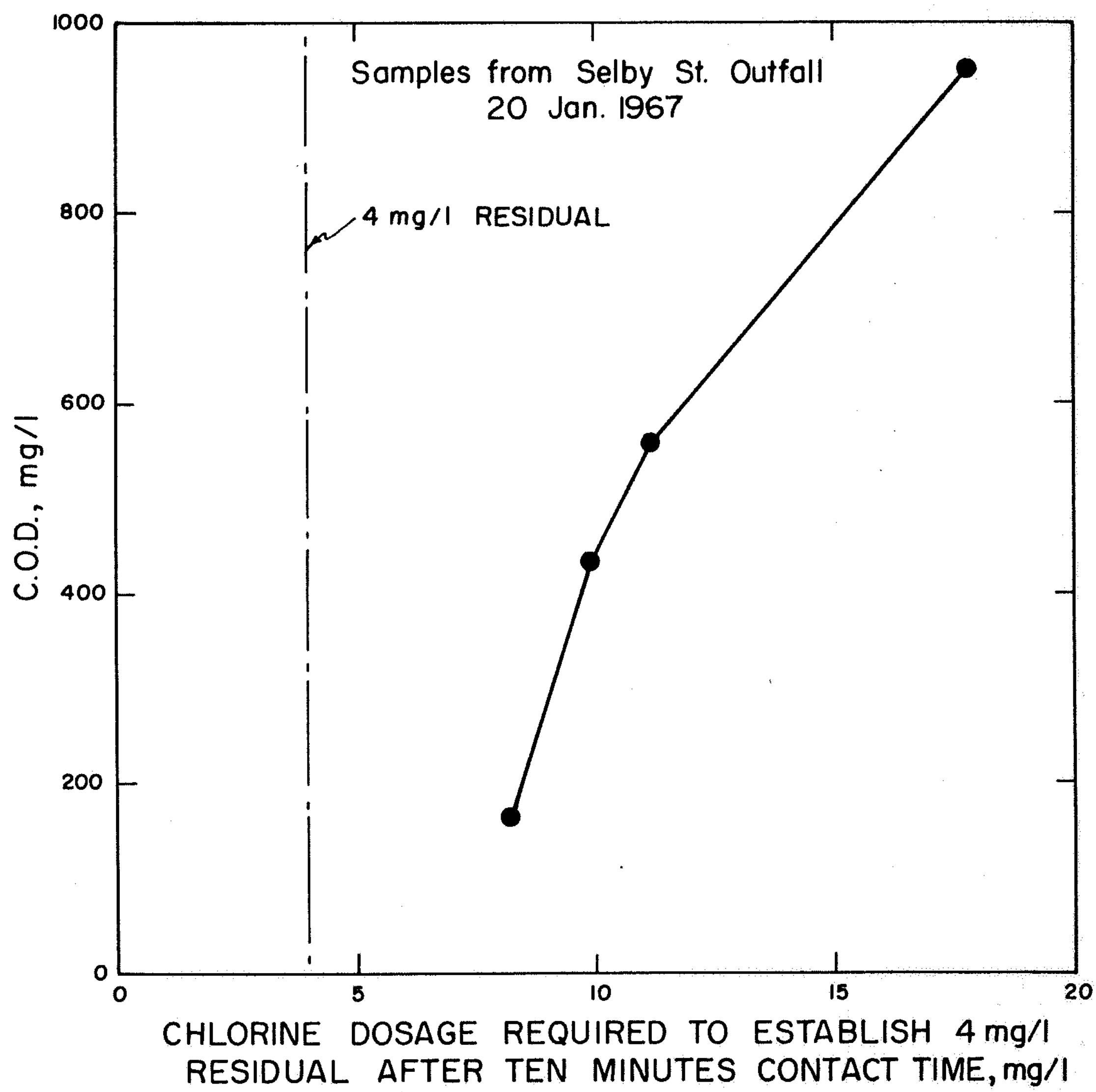
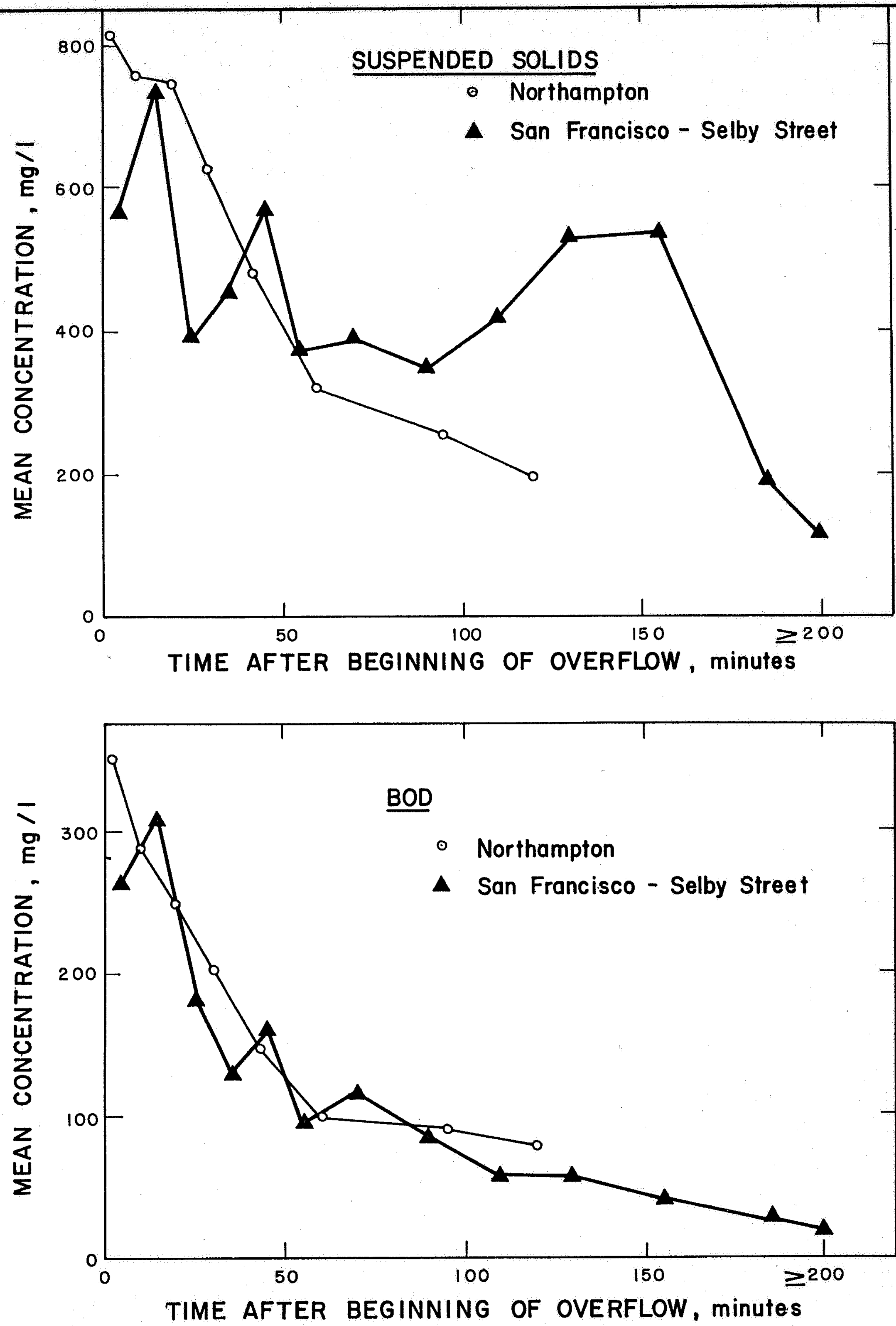
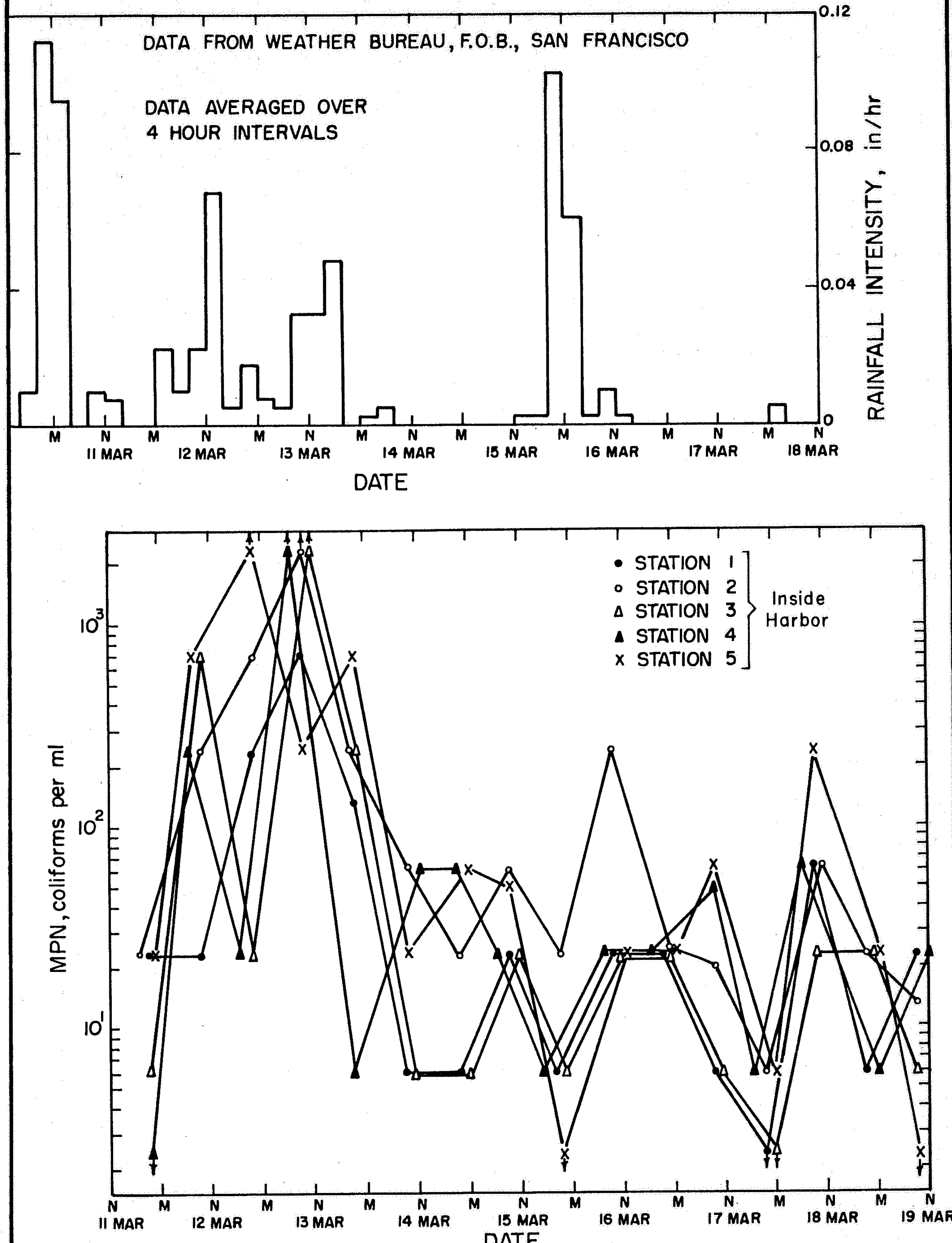
CHLORINE REQUIREMENTS FOR COMBINED SEWER OVERFLOWS AS A FUNCTION OF C.O.D.



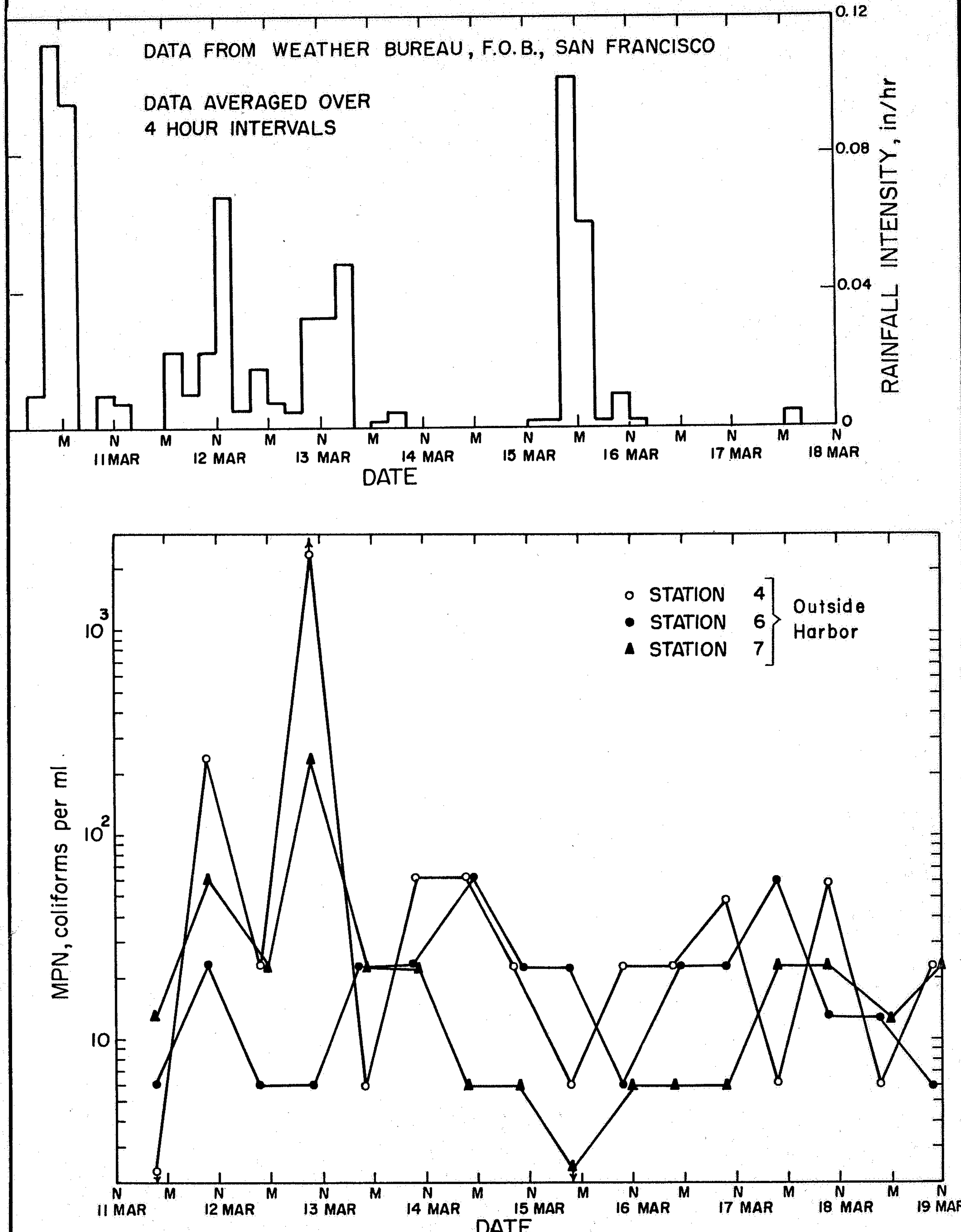


COMPARISON OF RESULTS FROM SAN FRANCISCO AND NORTHAMPTON, ENGLAND (II)

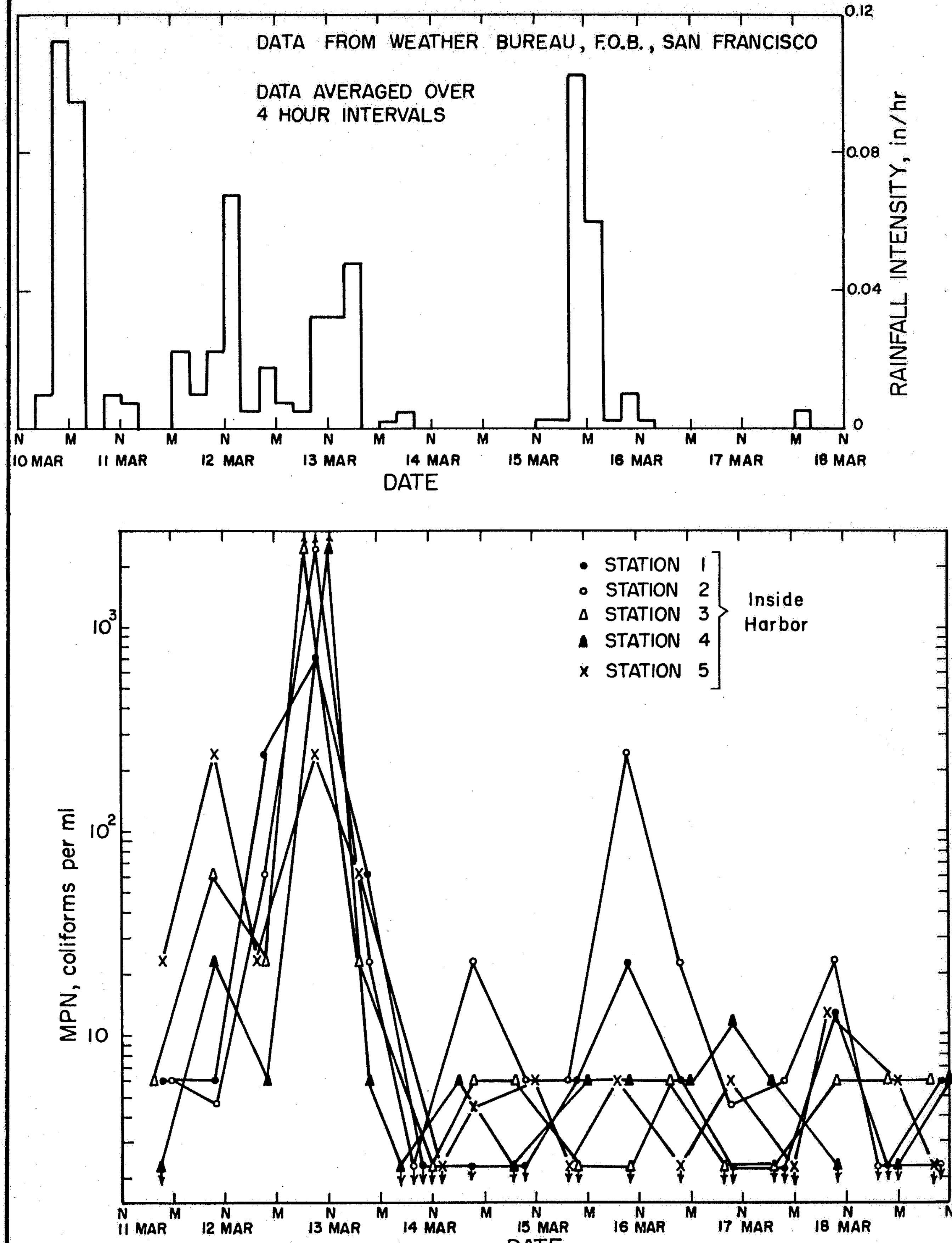


RAINFALL INTENSITY AND CONFIRMED COLIFORM MPN'S IN LAGUNA OUTFALL RECEIVING WATERS - MARCH 1967

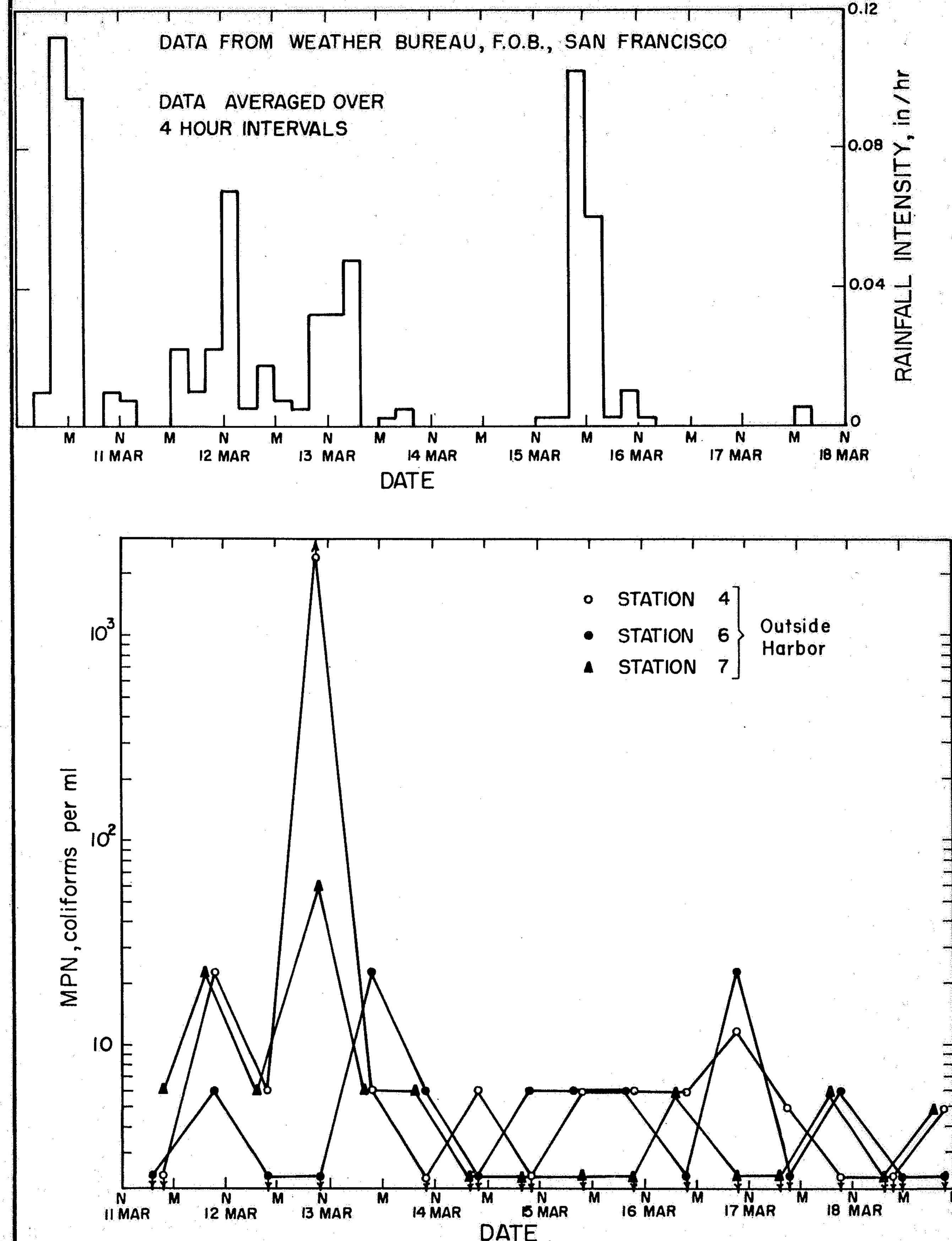
FIGURE V- 25



RAINFALL INTENSITY AND CONFIRMED COLIFORM MPN'S IN LAGUNA OUTFALL RECEIVING WATERS - MARCH 1967

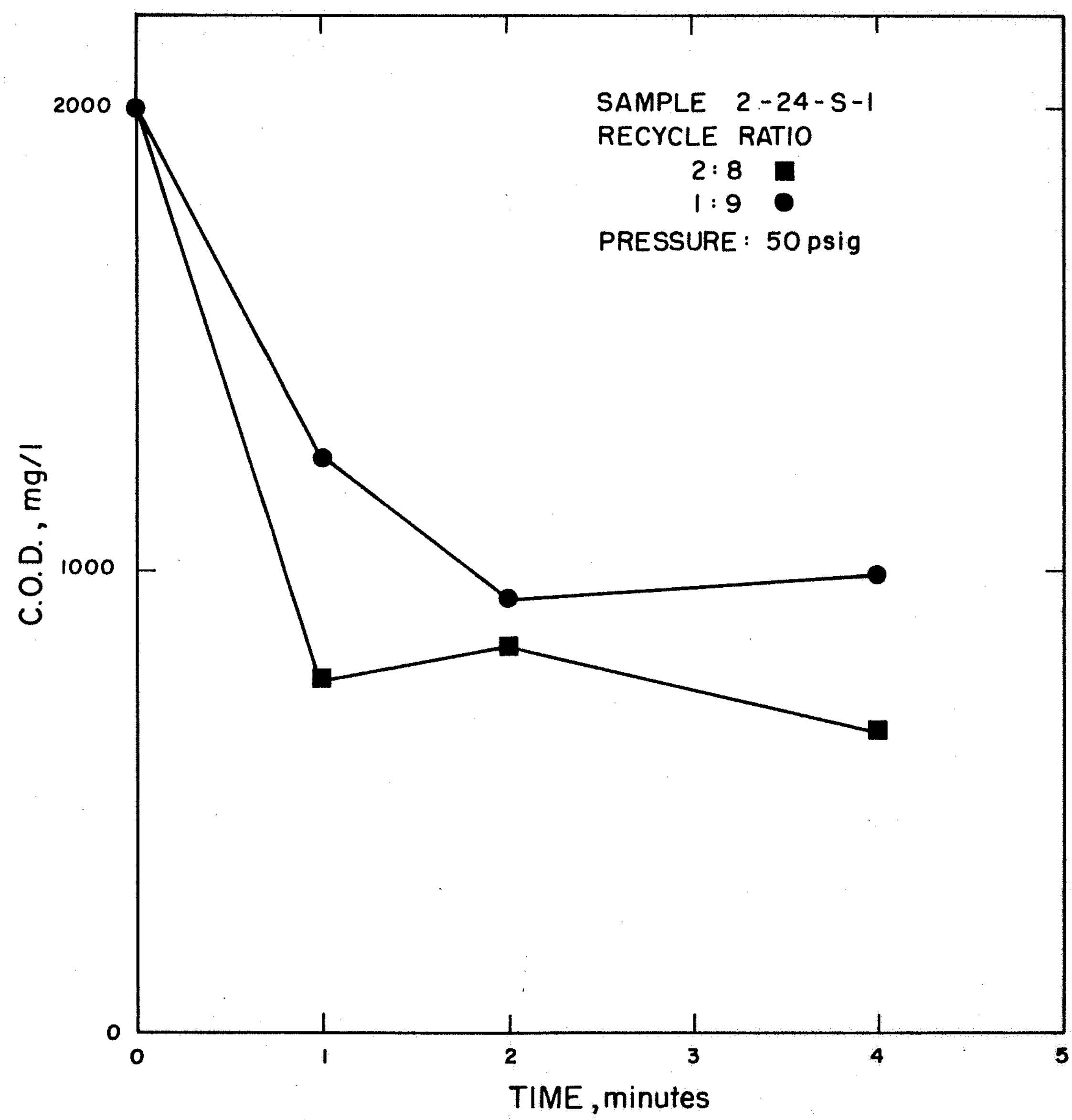


RAINFALL INTENSITY AND FECAL COLIFORM MPN'S IN LAGUNA OUTFALL RECEIVING WATERS - MARCH 1967

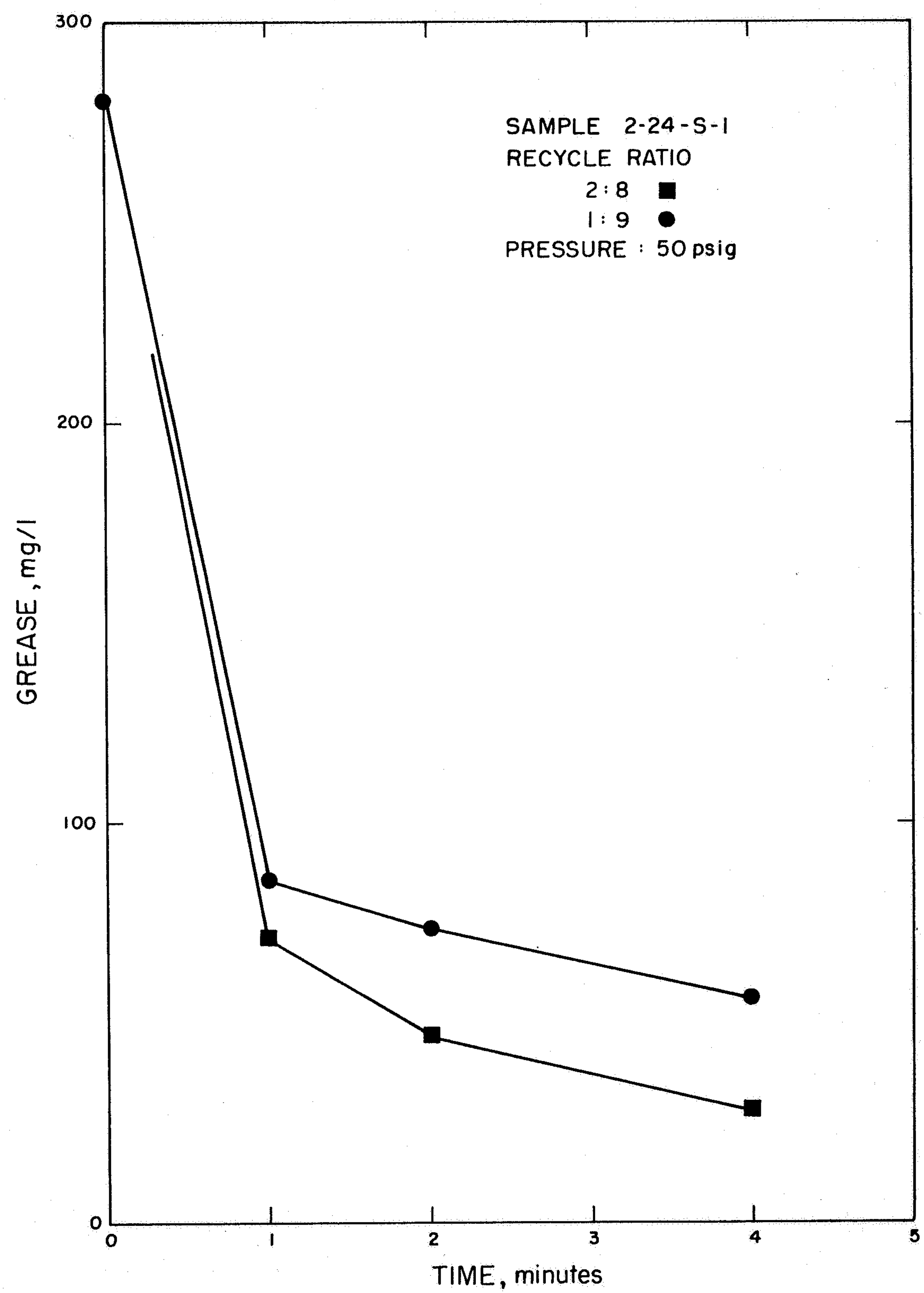


RAINFALL INTENSITY AND FECAL COLIFORM MPN'S IN LAGUNA OUTFALL RECEIVING WATERS - MARCH 1967

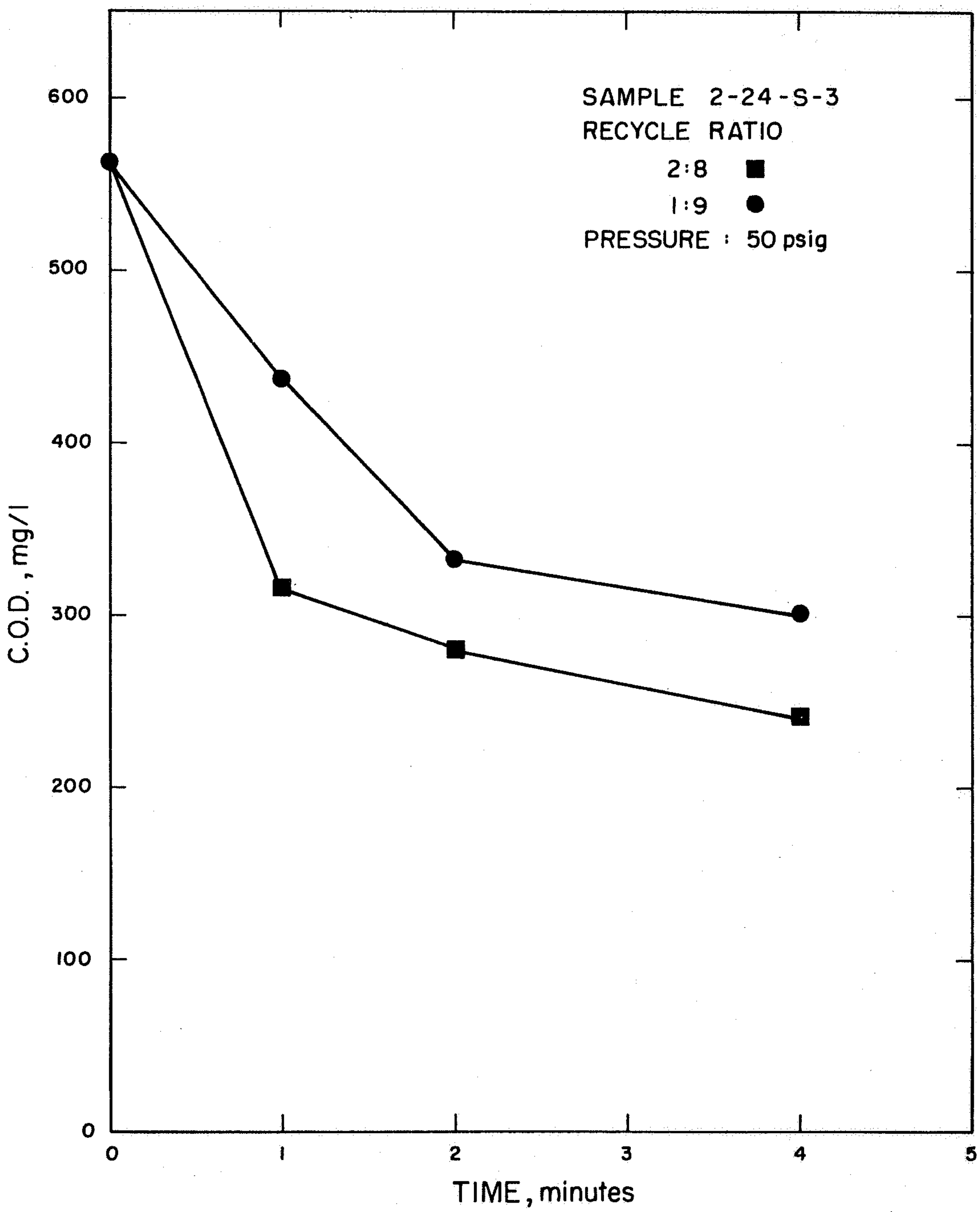
RESULTS OF LABORATORY DISSOLVED AIR FLOTATION TESTS (C.O.D.)



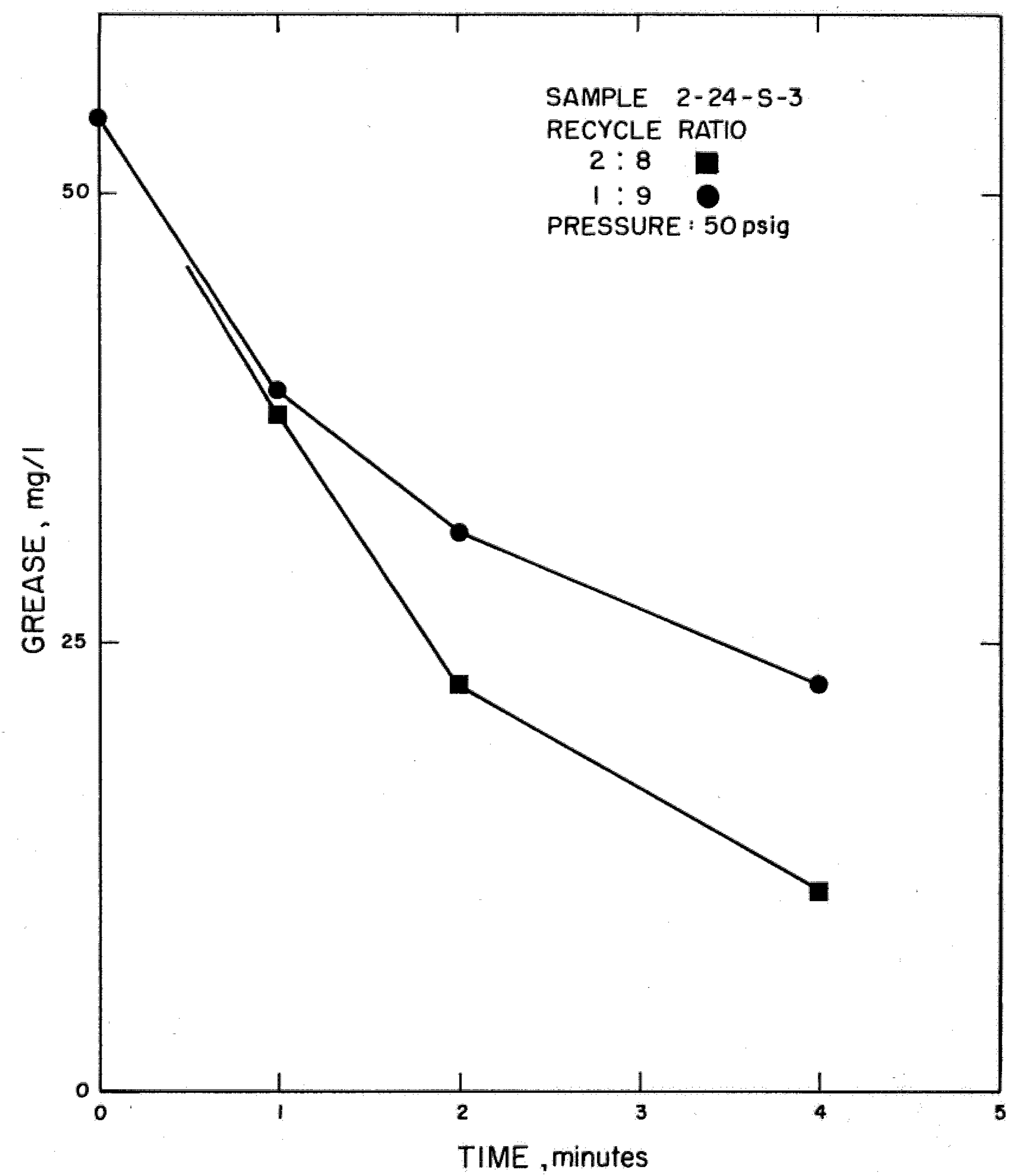
RESULTS OF DISSOLVED AIR FLOTATION TESTS (GREASE)

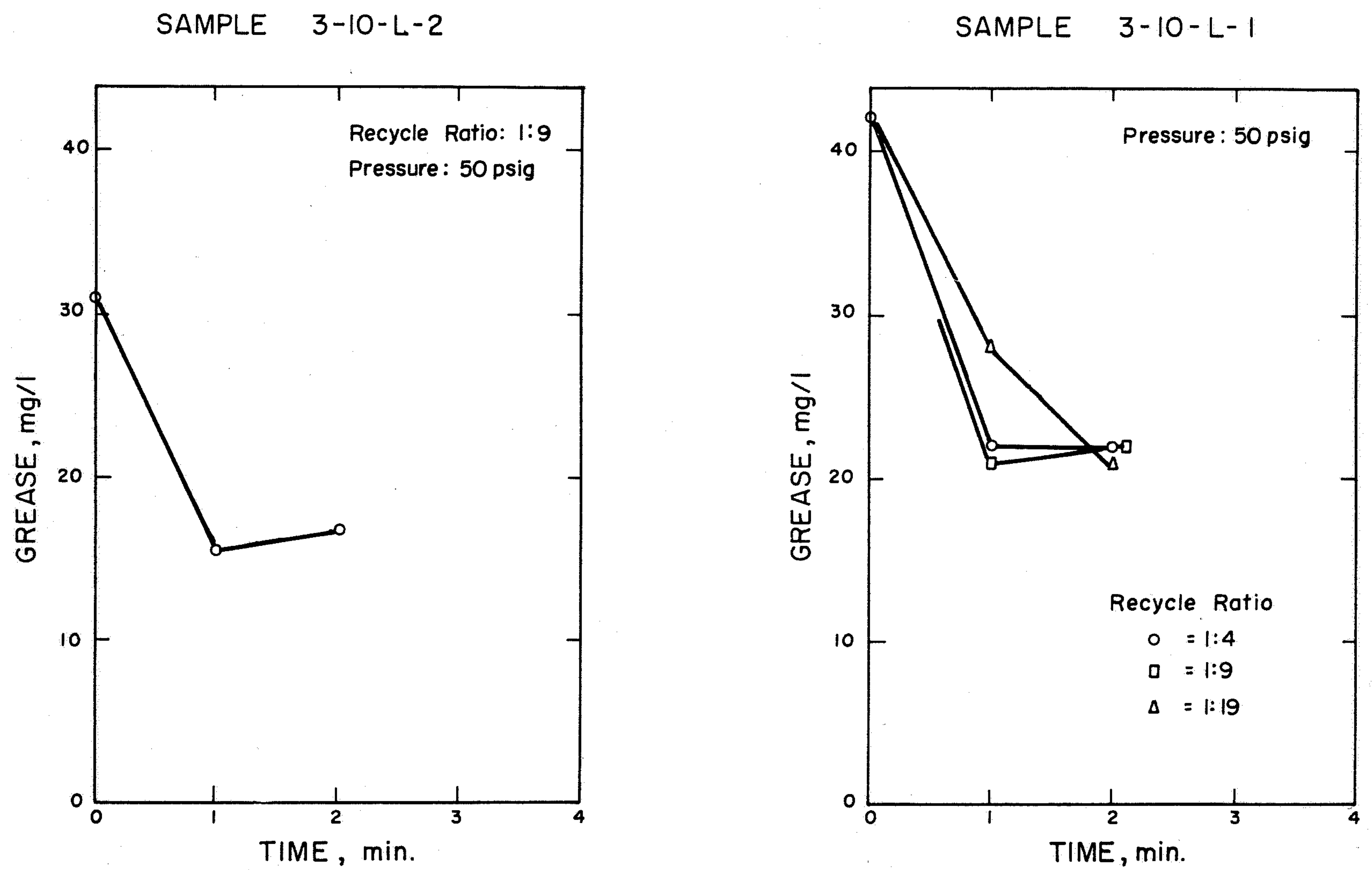


RESULTS OF LABORATORY DISSOLVED AIR FLOTATION TESTS (C.O.D.)



RESULTS OF DISSOLVED AIR FLOTATION TESTS (GREASE)





RESULTS OF LABORATORY DISSOLVED AIR FLOTATION TESTS

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Dry Weather Flows

1. The results of the dry weather monitoring program indicated that the pilot sectors studied were characteristic of urban areas of the United States. Comparisons of the dry weather monitoring data with published information indicated that in terms of both quality and quantity, the sewage flows originating in the two pilot sectors are typical, as are their diurnal variations. Table VI-1 summarizes the pertinent features of the pilot sectors and their dry weather sewage flows.

TABLE VI-1

CHARACTERISTICS OF PILOT SECTORS AND DRY WEATHER SEWAGE FLOWS

Characteristics	Pilot Sector: Selby St.	Pilot Sector: Laguna St.
Area	3,400 acres	370 acres
Land Use	Balanced Urban Community	Multiple Residence-Commercial
Mean Dry Weather Sewage Flow	7.77 mgd 96 gpcpd	2.68 mgd 107 gpcpd
Mean Concentrations:		
COD	456 mg/l	430 mg/l
BOD	164 "	179 "
SS	209 "	194 "
VSS	148 "	162 "
Grease	45 "	45 "
Nitrogen (N)	32 "	31 "
Phosphate (PO_4)	9.1 "	7.9 "
Coliforms (MPN) - Total	5.7×10^5 per ml	4.7×10^5 per ml
- Fecal	4×10^4 " "	3.5×10^4 per ml

One of the yet unexplained observations is the approximately 10:1 ratio of total coliforms to fecal coliforms in the dry weather flow.

Combined Sewer Overflows

2. The combined sewer overflow sampler developed during this study permitted an accurate quantitation of the characteristics of combined sewer overflows. Described in detail in Appendix A, the sampler consists of a traveling vertical cylinder which removes elements from each level of the overflow stream.

3. The calculated total runoff factor (ratio of runoff to rainfall) for the Selby Street area was 0.59 and for the Laguna Street area it was 0.70.

These factors are consistent with the physiographic characteristics of the two areas. The Laguna Street area has significantly less open space and vegetation than the Selby Street area. It is likely that runoff factors for the remainder of the city range between 0.60 and 0.70. On this basis, approximately nine billion gallons of surface runoff are discharged annually directly into San Francisco Bay and the ocean. In comparison, about 33 billion gallons of primary effluent are discharged from the City's sewage treatment plants.

4. The concentrations of the various quality parameters follow definite patterns with respect to elapsed time after discharge begins. The rate of discharge appears to have little influence on the concentrations. It is postulated that the transport of storm water contaminants takes place in three phases. The first phase begins with the accumulation of sewage in the lower reaches of the sewer systems, which discharges as a plug, and consequently, initially the overflows have the characteristics of raw sewage. The second phase involves the outflow of retained materials from the land surface and sewer system. After the cleansing action of the rainfall and runoff has removed the easily transported materials, the overflows represent the mixing of relatively large quantities of clean surface runoff with small amounts of sewage. In general, these Phase III overflows are relatively innocous.

5. Comparisons with the limited amount of other data available showed that the quality patterns obtained in this study appear to be generally characteristic of urban areas. It is believed that the uniqueness of individual domestic sewerage systems is not a major factor. However, runoff from principally industrial areas may have singular characteristics which would warrant special consideration.

6. It was observed that the quality characteristics of all combined sewer overflows from a given area preceded by more than one day of dry weather are nearly identical. It appears that there is little difference between the concentrations of pollutants discharged during a storm having two days of antecedent dry weather and the concentrations of these constituents in the first storm of the season. These observations strongly imply that in-system storage of materials from dry weather flows is not a major factor in pollution from combined sewer overflows. This aspect will receive further attention in studies recommended for the second year. It is intended to conduct materials balance studies of a combined sewer system in which input and output are quantitated, allowing the determination of the magnitude of in-system storage as a function of antecedent dry period.

7. Coliform organism concentrations (MPN's) in combined sewer overflows averaged approximately $5x10^4$/ml (about 10 percent of dry weather flows). They showed the same type of time-dependent decrease as the other quality parameters, varying from dry weather flow values of approximately $5x10^5$/ml to less than 10^4/ml.

8. Bioassays conducted on samples of dry weather flows and the most polluted portions of the combined sewer overflows indicated that the median tolerance limit (TL_m) of the test fish to both wastes was about the same. For dry weather flow samples (COD = 450 mg/l) and combined sewer overflow

samples (COD = 1,760 mg/l), the 96-hr TL_m's were 38 percent and 35 percent, respectively. Hence it appears that there is no signficant toxicity increase due to materials present because of surface runoff. As toxicity problems seldom result from domestic waste discharges, it is concluded that no problems of this nature should be expected from combined sewer overflows.

9. Chlorine demand tests carried out on samples from combined sewer overflows showed that there is a high dependence on the organic strength of the waste. In general an average chlorine dose of 10 to 15 mg/l should be sufficient to achieve total chlorine residuals of 4 mg/l after 10 minutes of contact, although doses of 20 to 25 mg/l may be required during periods of maximum organic strength. Previous work by the City has demonstrated chlorine residuals of 4 mg/l after 10 minutes contact are adequate for purposes of disinfecting primary sewage effluents, and this conclusion is based on the assumption that identical results will be obtained with combined sewer overflows. Further studies of chlorine requirements are recommended for subsequent research.

10. Analyses conducted on settled overflow samples demonstrated that the macroscopic particulate fractions of the various pollutants were quite significant. Approximately 75 percent of the volatile suspended solids were removed in 30 minutes of settling in an Imhoff cone and the average COD was reduced about 60 percent. In separate tests, BOD reductions of 53 percent were obtained. The potential of physical treatment methods is implicit in these results.

Relationships of Combined Sewer Overflows and Other Waste Discharges

11. Comparisons of the mass discharges of the various pollutants in combined sewer overflows with dry weather flows showed that domestic sewage contributes relatively little to the total mass of material (except for BOD) carried in combined sewer overflows. The exceptions are the nutrients nitrogen and phosphorus as a major fraction of these materials in the San Francisco system appears to originate with the municipal sewage. Previously reported data on urban surface runoff (7) substantiate these results. However, it is apparent that significant amounts of nutrients are contained in runoff from some urban areas. Table VI-2 summarizes the information.

TABLE VI-2

RELATIVE CONCENTRATIONS OF CONSTITUENTS IN COMBINED SEWER OVERFLOWS AND URBAN SURFACE RUNOFF

Constituent	Ratio of Mean Concentrations Combined Sewer Overflows/Urban Surface Runoff
BOD	4
COD	2
SS	1
VSS	1.5
N	1.8
PO_4	1.2

12. Additional comparisons of total annual pollutant discharges in primary and secondary sewage treatment plant effluents in combined sewer overflows and in urban surface runoff are made in Table VI-3. For most constituents, secondary effluents, combined sewer overflows, and urban surface runoff carry annual amounts of the same order of magnitude. However, the nitrogen and phosphorus discharged with secondary effluents amount to one to two orders of magnitude more than that contained in both combined sewer overflows and surface runoff from separate storm drains.

Impact of Combined Sewer Overflows on the Bacteriological Quality of Receiving Waters

13. Receiving water investigations yielded results which agreed with the previously known fact that combined sewer overflows have a considerable impact on the bacterial quality of receiving waters. Coliform MPN's in the range of 1,000 per ml were observed in the relatively confined municipal marina which serves as the receiving water for the Laguna Street combined sewer outfall. It was found, however, that rapid reductions in the MPN's took place. It is estimated that the time required for a 90 percent decrease was approximately 12 hours. On the other hand, residual coliform concentrations were consistently higher following periods of overflow, being about two to three times greater than in dry weather periods and appearing to persist for about two weeks.

Control of Pollution From Combined Sewer Overflows: Separation of Combined Sewer Systems

The data developed in this study and compared with previous work involving urban surface runoff demonstrate the questionable feasibility of separating urban combined sewer systems. Based on information in Table VI-3, which compares annual per acre mass discharges from various waste effluents, the following specific conclusions were drawn:

14. For urban areas in which primary treatment of dry weather flows is practiced, annual mass discharges from treatment plant effluents far exceed those from combined sewer overflows. For most constituents the difference is an order of magnitude or greater.

15. Annual mass discharges from secondary effluents are nearly equal to those from combined sewer overflows (except for nitrogen and phosphorus) from urban areas in which the annual rainfall is about 20 inches. On the other hand, the annual mass discharge of nitrogen and phosphorus with secondary effluents exceeds by about 50 times the quantities of these constituents carried by combined sewer overflows from urban areas.

16. The fractional reduction of mass discharges achieved by separating combined sewer systems would be negligible if no treatment of urban runoff were practiced. Only for the constituents BOD and COD would the reductions be significant. On the other hand, these studies have demonstrated that treatment of combined sewer overflows would result in substantial reductions of all pollutional constituents at less expense than would be involved in the separation of combined systems. Therefore it is concluded that treatment is a more feasible alternative solution to the problem of pollution from

TABLE VI-3

ANNUAL MASS DISCHARGES AT SELBY STREET
(lb/acre-yr)

Constituent	Primary Effluent*	Secondary Effluent**	Combined Sewer Overflow	Urban Surface Runoff***
BOD	1,450	175	101	25
COD	2,420	280	447	188
SS	1,415	105	632	570
VSS	990	84	146	125
Grease	344	14	36	-
N	250	175	10.6	7.0
PO_4	262	210	2.4	2.0

* At Southeast Sewage Treatment Plant.

**Assuming standard rate treatment of the primary effluent.

***Calculated from Mass Discharge Factors from Cincinnati (see Table V-7) and annual runoff from Selby Street sector.

combined sewer overflows than is the separation of combined systems.

Control of Pollution From Combined Sewer Overflows: Treatment Methods

17. The worst quality segments of combined sewer overflows occur during the first two hours of runoff. If storage of the initial portions of runoff could be accomplished, the pollution load on the receiving waters would be substantially reduced. The stored volume could be subsequently diverted to a sewage treatment plant where stripping of much of the objectionable material could take place.

The principal disadvantage of storage tanks is the large size requirement. In San Francisco a two-year storm of two hours duration has an intensity of 0.35 inches per hour. To retain the runoff from such a storm would require approximately four acre feet of storage per 100 acres of drainage area. For the Selby Street Outfall the required storage would amount to 136 acre feet. In most metropolitan areas and especially in San Francisco the space needed to construct such facilities is not available. However, the economics of storage should be explored in a systematic fashion so that a rational comparison can be made with other methods for solving the combined sewer overflow pollution problem.

18. Sedimentation: Analysis of the macroscopic particulate fractions of several pollutional constituents demonstrated the potential of physical methods for the treatment of combined sewer overflows. Sedimentation therefore was a candidate process although it was recognized that the laboratory Imhoff cone results would not be indicative of field performance of sedimentation units. In the first place, the nominal surface loading rate of an Imhoff cone (at 30 min settling time) is approximately 110 gsfd, whereas continuous flow units for combined sewer overflow treatment would necessarily have to be designed for a much higher surface loading rate in order to be competitive with other methods of treatment. Secondly, the quiescent conditions of the Imhoff cone are unattainable in continuous flow units.

Perhaps the most objectionable feature of sedimentation is that floatable materials, including particulates as well as oils and greases, tend to be largely unaffected by sedimentation. One of the primary objectives of combined sewer overflow treatment should be to restrict the discharge of floatables, and it is believed with ordinary sedimentation this objective cannot be fulfilled.

19. Screening: The passage of greases and oils would cause this technique to be ineffective in achieving the aforementioned principal objective. However, it is possible that in conjunction with other processes, screening may be an effective adjunct method for the treatment of combined sewer overflows. Further exploratory work on the development of satisfactory screens and screening techniques should be considered. Judging from the relative size of screening units, the economic benefits which would result from a successful treatment process would be substantial.

20. Dissolved Air Flotation: The attractive features of dissolved air flotation, as previously mentioned and as demonstrated in this investigation, are:

a. Selective removal of floatable materials, including oils and greases, occurs.

b. Removal of particulate materials is effected through nucleation and growth of air bubbles on the surface of the particulates. The bulk specific gravity of materials not amenable to sedimentation can be altered, causing them to float to the surface where they can be easily removed.

c. Relatively high surface loading rates can be employed. It appears that satisfactory removal of grease (hexane extractables) can occur at surface loading rates of 6,000 gsfd. Thus size requirements can be much smaller than those associated with other continuous flow processes.

The laboratory results obtained in this investigation demonstrated the potential feasibility of dissolved air flotation as a means of treating combined sewer overflows. Tentative design specifications for the process are a surface loading rate in the range of 5,000 gsfd and a pressurized recycle rate of 10 to 20 percent.

This process should be examined in greater detail since it could very well economically solve a major part of the combined sewer overflow problem.

21. Disinfection: The receiving water studies conducted as part of this investigation emphasized the point that disinfection of combined sewer overflows will be an essential part of treatment if existing recreational water quality standards are to be maintained. Based on previous studies conducted by the City and experiments carried out on combined sewer overflow samples in this program, it is concluded that chlorination of combined sewer overflows would be an effective and economical means of disinfection. In order to maintain the desired chlorine residual (4 mg/l after 10 minutes of contact) a chlorine dosage of 10 to 15 mg/l would be required. The annual chlorine requirements for San Francisco, based on an average annual rainfall of 20 inches and a runoff factor of 0.65, would be 400 to 500 tons.

Chlorination could be accomplished readily in conjunction with other schemes, such as the dissolved air flotation process, since contact time would be provided during the residence of the overflow in the process.

RECOMMENDATIONS

Although this investigation has provided definitive information on several aspects of combined sewer overflows, there are other important factors which should be explored in subsequent studies. Detailed recommendations are enumerated below.

1. The major conclusion of this study has been that separation of combined sewer systems does not constitute a reasonable engineering solution to the pollution problems caused by combined sewer overflows. It has been furthermore demonstrated that treatment of combined sewer overflows by dissolved air flotation and chlorination represents one of the best means of control of such overflows from urban areas.

It is therefore recommended that a dissolved air flotation-chlorination facility be constructed on a minor combined sewer outfall in the City for purposes of demonstrating the feasibility of the processes on a full scale basis. Through a comprehensive program of operation and process monitoring, design and operating criteria for similar installations in other areas can be developed.

It is recommended that the facility be located on the Baker Street Outfall, which drains an area of about 200 acres on the northern shoreline of the City. Because this outfall discharges into waters principally used for recreational purposes, the recommended demonstration project would constitute an important element of an ultimate comprehensive combined sewer overflow control program as well as contribute to the technology of advanced waste treatment.

Factors which should be evaluated in the recommended demonstration project include:

a. Design surface loading rate
b. Recycle ratio
c. Air pressure
d. Pretreatment requirements (bar screens, etc.)
e. Float collection methods
f. Post-runoff solids handling techniques
g. Chlorine dose rates
h. Receiving water effects

Such a program would be of value not only to the City of San Francisco but to other urban areas as well.

2. Comparison of the results of this study with other data showed that substantial contributions of pollutants to combined sewer overflows are made by urban surface runoff. Efforts should be made to quantitate the relative pollutional contribution of surface runoff with respect to that originating in normal sewage discharges. The information to be obtained from such a study would be of value for two reasons. First, it would permit a better understanding of the character of combined sewer overflows, and secondly, it is possible that other treatment methods (for both combined sewer overflows and urban surface runoff) may become more evident if the quality characteristics of surface storm runoff are quantitatively analyzed.

3. Another important element of subsequent studies should be the characterization of surface runoff and combined sewer overflows from types of urban area not covered in this investigation. In particular, zones of heavy industrial activity should be monitored. Utilizing rainfall data, geophysical characteristics, and other pertinent information relative to urban areas, it should be possible to establish a rational methodology for the handling and treatment of combined sewer overflows from various urban environments.

4. Receiving water effects were studied in this investigation in terms of the bacteriological quality of the waters preceding and subsequent to combined sewer discharges. These studies should be continued to evaluate the full impact of these discharges on the aquatic environment of the receiving waters. The cause and effect relationships among various trophic

levels and specific overflow constituents should be determined. Information obtained from such studies would be of substantial value in the development of comprehensive programs for the control of pollution from combined sewer overflows for the protection of all receiving water uses.

5. The present study has demonstrated the potential of dissolved air flotation in the treatment of combined sewer overflows. Further laboratory and pilot scale experiments should be conducted to determine the feasibility of utilizing chemical additives in the treatment of overflows by dissolved air flotation as well as to provide design criteria. There is definite promise that the addition of chemical "flotation aids" will improve significantly the degree of treatment. Because this process has yet to be employed in situations involving combined sewer overflows, evaluation experiments of a practical nature should be conducted under a wide range of operating conditions. The effectiveness of chlorination in conjunction with dissolved air flotation should also be investigated.

6. A systematic analysis of local rainfall records should be conducted using computer techniques to develop a rational method of predicting the pollutional effects of known rainfall distribution patterns. This analysis will provide a methodology which will be extremely useful for purposes of design of combined sewer overflow treatment processes in the City as well as in other areas of the United States.

CHAPTER VII

REFERENCES

1. Palmer, C. L., The Pollutional Effects of Storm Water Overflows from Combined Sewers, Sewage & Industrial Wastes, 22: no 2, 154 (Feb 1950)

2. Sylvester, R. O., An Engineering and Ecological Study for the Rehabilitation of Green Lake, University of Washington, Seattle, Washington (1960)

3. Wilkinson, R., The Quality of Rainfall Runoff Water From a Housing Estate, Journal Institute Public Health Engineers, London (1954)

4. Shigorin, G. G., The Problem of City Surface Runoff Water, Vodosnabzhenie i Sanitamaya Tekhnika, 2: pg 19, (1956)

5. Akerlindh, G., The Quality of Storm Water Flow, Nordisk Hygienisk Tidskrift (Stockholm), 31: pg 1 (1950)

6. Stander, G. J., Topographical Pollution, 40 Annual Conference, Institution of Municipal Engineers, National Institute for Water Research, (1961)

7. Weibel, S. R., Anderson, R. J., and Woodward, R. L., Urban Land Runoff as A Factor in Stream Pollution, Journal Water Pollution Control Federation, 36: no 7, pg 914 (July 1964)

8. Pollutional Effects of Stormwater and Overflows from Combined Sewer Systems, U. S. Dept. of Health, Education, and Welfare (Nov 1964)

9. Dunbar, D.D., and J. G. F. Henry, Pollution Control Measures for Storm Waters and Combined Sewer Overflows, Journal Water Poll. Control Fed., 38 (1), 9 (Jan 1966).

10. Romer, H., and Klashman, L., The Influence of Combined Sewers on Pollution Control, Public Works, 92: no. 10, 129-133 (Oct. 1961)

11. Gameson, A.L.H., and Davidson, R.N., Storm-Water Investigations at Northampton, Journal and Proceedings Institute of Sewage Purification, Part 2: pg 105 (1963)

12. Anon., Dig Deep to Store Storm Water, Engineering News - Record (July 1965)

13. Anon., City Plans to Treat Storm Water, Engineering News - Record (May 28, 1964)

14. King, H.W., Handbook of Hydraulics, McGraw-Hill Book Co., New York (1954)

15. Analytical Methods, Sanitary Engineering Research Laboratory, University of California, Berkeley (March 1966).

16. Standard Methods for the Examination of Water and Wastewater, Eleventh Edition, American Public Health Association, New York (1960).

17. Determination and Removal of Floatable Material From Waste Water, Engineering-Science, Inc., Arcadia, California (1965)

18. Fair, G.M., and J. C. Geyer, Water Supply and Waste-Water Disposal, John Wiley & Sons, Inc., New York (1961)

19. Babbitt, H.E., and E. R. Baumann, Sewerage and Sewage Treatment, John Wiley & Sons, Inc., New York (1964)

20. Geldreich, E.E., R. H. Bordner, C.B. Huff, H. F. Clark, and P. W. Kabler, Type Distribution of Coliform Bacteria in the Feces of Warm-Blooded Animals, Journ. Water Poll. Control Fed., 34: (3), 295 (March 1962)

21. Robeck, G. G., Private Communication, (July 1967)

APPENDIX A

DESCRIPTON OF ENGINEERING-SCIENCE COMBINED SEWER OVERFLOW SAMPLER

APPENDIX A

DESCRIPTION OF ENGINEERING-SCIENCE COMBINED SEWER OVERFLOW SAMPLER

PRINCIPLE

Combined sewer overflows are usually highly stratified with respect to the particulate materials they carry, and a representative sample therefore must contain a portion of each element of the flowing stream. The Engineering-Science combined sewer overflow sampler achieves the objective of obtaining representative samples by means of "coring" the waste flow from top to bottom. Samples are mixed within the coring apparatus and ejected to a sample receiver by means of compressed air.

CONSTRUCTION

The sampling tube consists of 12-inch well casing, which is contained in a set of four 2-inch steel pipe guides. The unit is supported on a steel base plate, which is firmly attached to the invert of the overflow channel. The sampling tube is raised by means of a block and tackle apparatus, suspended from a cross-member at the top of the sampler guides.

Two of the sampler guides are fitted with 180^{o} elbows at the base plate. The elbows return to the base plate within the area enclosed by the sampling tube. One of the sample guide-elbow conduits serves as the compressed air supply to the sampling tube; the other carries the mixed sample to the sample receiver.

Figure A-1 shows the arrangement of the components, and Figure A-2 shows the installation of a sampler at Selby Street.

OPERATION

1. Prior to sampling, the travelling cylinder (sample tube) is in the raised position, which allows the flowing stream to pass through the guide bars.

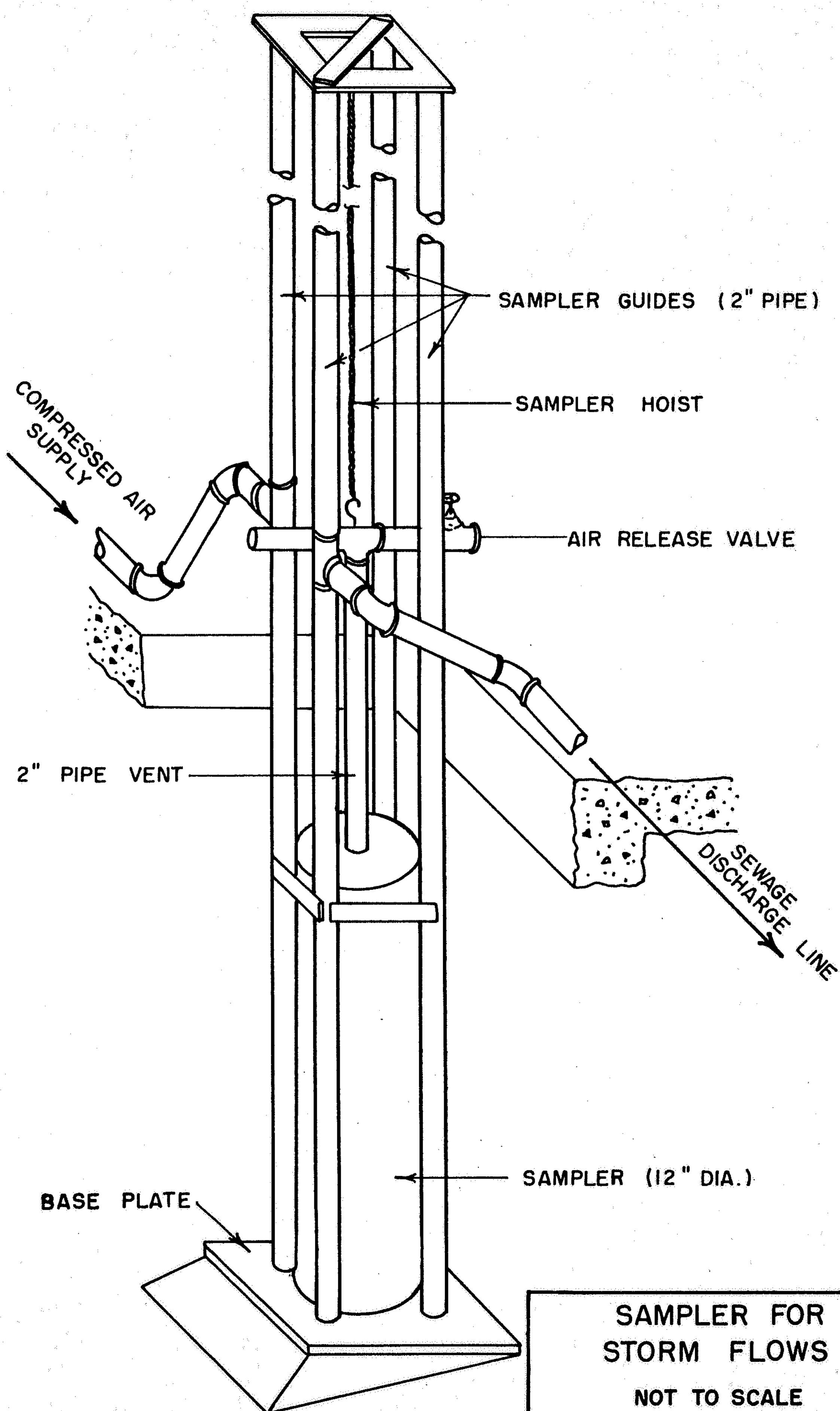
2. The air release valve is opened and the cylinder is dropped into the sampling position and twist locked.

3. Prior to closing the air release valve, the compressed air supply valve is opened for a short period of time, which causes the cylinder contents to be thoroughly mixed.

4. The air release valve is closed and the compressed air supply valve opened, causing the cylinder contents to become pressurized. The increased air pressure in the cylinder forces the mixed sample up through the discharge guide bar tube and the mixed sample discharges into a receiving container.

5. After the internal cylinder pressure has been released, the travelling cylinder is unlocked and raised into position for subsequent sampling.

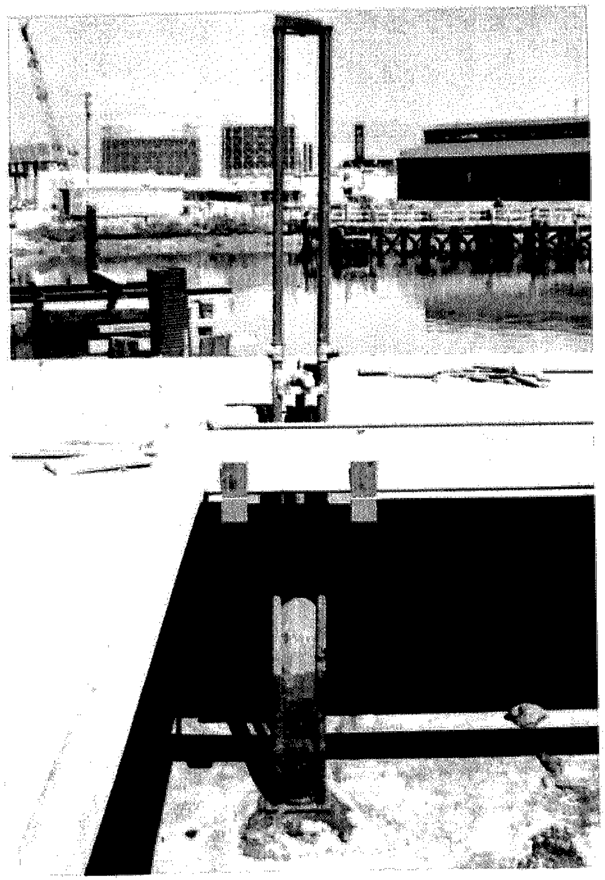
FIGURE A-1

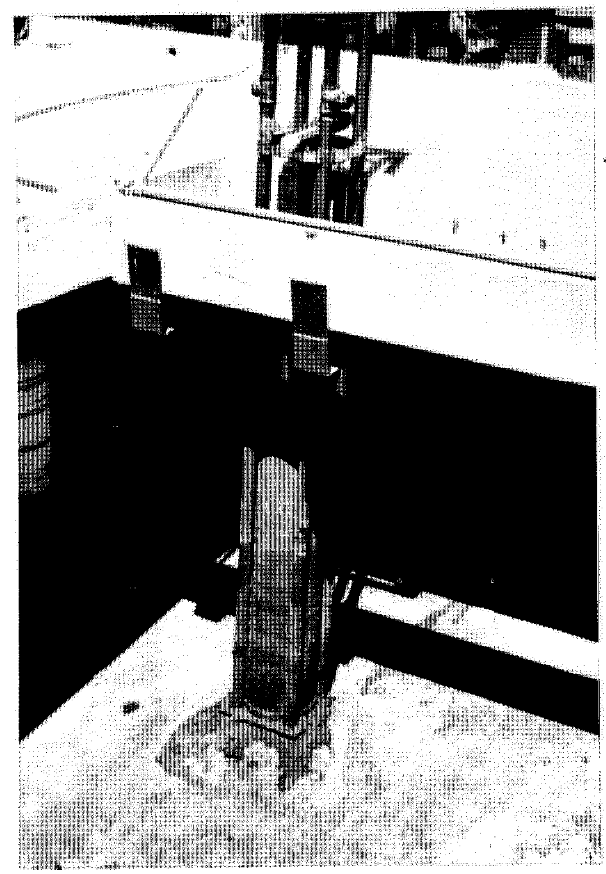


SAMPLER FOR STORM FLOWS

NOT TO SCALE

ENGINEERING-SCIENCE, INC.





COMBINED SEWER OVERFLOW
SAMPLER, SELBY STREET

FIGURE A-2

ENGINEERING - SCIENCE, INC.

APPENDIX B

LABORATORY METHODS

APPENDIX B

MODIFIED COD PROCEDURE

1. Place 25 ml of oxidizing agent in a 125 ml erlenmeyer flask, add about 0.5 gms of silver sulfate ($AgSO_4$) and 10 mg $HgSO_4$ for EACH 1 mg Cl^- in sample.

2. Add appropriate ml of sample (between 1.0 and 5.0 ml) so that COD will be between 10 and 3,000. Dilute sample with distilled water if extremely high. Then add from 1-5 ml sample using correction factor.

3. Heat to 165^{o} C within 3-5 minutes.

4. Let cool to room temperature then fill up to the top with distilled water, swirling to mix well.

5. Let come to room temperature again.

6. Transfer to a 250-300 ml erlenmeyer flask, rinse 3 times adding all rinsings to flask.

7. Add 3 drops ferroin indicator to the flask.

8. Titrate with 0.05 N ferrous ammonium sulfate ($FeSO_4$ $(NH_4)_2$ SO_4) until the light blue color changes to a brick red. Initial color after adding ferroin will be yellow. Do not add ferroin to a hot sample.

9. Carry out steps 1 thru 8 on a distilled water blank (5 ml) as the sample

$$\text{COD} = \frac{\text{(Blank titer-sample titer) x normality of FAS x 8 x 1000}}{\text{ml of sample used}}$$

Reagents:

1. Oxidizing agent: 500 ml Conc. H_2SO_4, 500 ml conc H_3PO_4 (phosphoric acid) 2.5 gms of $K_2CR_2O_7$ (Potassium Dichromate). Dissolve dichromate in about 25 ml distilled water before adding acid.

2. Ferrous Ammonium Sulfate ($FeSO_4$ $(NH_4)_2$ SO_4). Dissolve 20 grams of FAS in distilled H_2O. Add 5 ml conc. H_2SO_4 (sulfuric acid) then make mixture up to 1 liter with dist. H_2O.
Standardize FAS solution using 0.025 N Potassium dichromate standard solution (K_2 CR_2 O_7).

   a. To approx 150 ml dist. water add 50 H_2SO_4 (1+3) cool, add 20 ml 0.025 N K_2 CR_2 O_7. Add 3 drops ferroin indicator, titrate with FAS to brick red color on standing.

$$N_{FAS} = \frac{\text{ml } K_2\ CR_2\ O_7 \text{ x } 0.025}{\text{ml FAS used}}$$

3. Ferroin indicator solution. Dissolve 1.485 g 1-10 phenanthroline (monohydrate) together with 0.695 g $FeSO_4 \cdot 7H_2O$ and dilute to 100 ml with dist H_2O. This indicator solution can be purchased already prepared from the G. Frederick Smith Co., Columbus Ohio.

4. Silver Sulfate ($AgSO_4$) add about 0.5 grams to each flask before adding sample or heating. Reagent grade crystals.

5. Mercuric Sulfate ($HgSO_4$) Reagent grade, low in mercurous mercury add $HgSO_4$ in the ratio of 10 mg for each mg Cl^- present in sample.

Accuracy and Precision

A correlation with the Standard Methods (16) procedure is given in Figure B-1.

APPENDIX B

LIQUID-LIQUID EXTRACTION OF OIL AND GREASE FROM SEWAGE

GENERAL DISCUSSION

Principle: The salts of the fatty acids are first hydrolyzed by acidification and heating for one hour. Oil and grease is then extracted in a continuous extractor, and the residue remaining after evaporation of the solvent is weighed. Compounds volatilized at or below 85° C will be lost.

Interferences: This method is subject to the same interferences as the Soxhlet Extraction Method.

APPARATUS

Sampling Bottle: A 1-liter Pyrex flask provided with a 34/45 standard ground glass joint and a 1000 ml calibration mark.

Water Bath: Water bath which can be adjusted to 72° - 75° C.

Extraction Apparatus: A Pearson extraction apparatus as shown in Figure B-2.

Glass Filter Paper: Whatman GF/c. 4.25 cm.

Magnetic Stirrer: Precision Scientific Catalog No. 65904 with a 1-1/2 inch Teflon coated stirring bar.

Hot Plate

Aluminum Dishes: 5.5 cm, Van Waters & Rogers, Inc. Catalog No. 25433.

REAGENTS

Hydrochloric acid, conc.

n-Hexane, boiling point 68-69° C, purified grade.

PROCEDURE

Collect a 1-liter volume of sewage in the sampling bottle (which also serves as extraction chamber) and acidify by adding 10 ml conc. HCl. Place the acidified sample in the 72-75° C water bath for one hour. Remove and cool to below 65° C.

Place the Teflon coated magnetic stirring bar in the extraction flask; place the glass filter paper and the monel screen in the cylinder and assemble the extraction apparatus as shown in Figure B-2. Seal the 34/45 joint at the top of the extraction flask with distilled water. Add 150 ml hexane to the Erlenmeyer flask and set the mixer at speed 7 (to obtain a small vortex). Start the extraction and adjust the hot plate so the extraction rate is between 400 ml and 600 ml hexane per hour. (Between 15 minutes and 20 minutes from the time the hexane begins to condense in the top condenser till it starts overflowing back into the Erlenmeyer flask). Extract for three hours, turn off the hot plate, wait five minutes (fire hazard), and remove Erlenmeyer Flask.

Evaporate the hexane in the Erlenmeyer flask on a water bath or steam bath till only 10-15 ml are left. Transfer quantitatively to a predried and weighed set of aluminum dishes (rinse three times with hexane from a glass wash bottle). The set of aluminum dishes is made by widening the sides of one dish and placing a similar dish inside the first dish (to prevent losses by creeping). Evaporate the hexane in the dishes to dryness at room temperature. Place dishes in an 85° C oven for 5 minutes, cool in a desiccator for 15 minutes and weigh. Repeat drying procedure until observed weight change is less than 0.5 mg for 5 minutes drying.

CALCULATIONS

mg/l Hexane Extractable Material =

$$\frac{(\text{mg increase in weight of dishes - blank}) \times 1000}{\text{ml sample extracted}}$$

PRECISION AND ACCURACY

An average recovery of 98.5 percent with a standard deviation of 2.3 percent was obtained on Crisco standards. Replicate analyses of three sewage samples containing from 30 mg/l to 100 mg/l Hexane Extractable material yielded standard deviations between 0.7 mg/l and 1.0 mg/l. The coefficient of variation varies from one to three percent in this range.

SPECIAL PRECAUTIONS

Mixing: The mixing speed is very critical. The speed of the mixer should be such that the refluxing hexane is dispersed in small droplets throughout the sample being extracted and a small vortex created. The speed is best adjusted when extracting a clear water sample.

Blanks: The purified hexane varies from batch to batch. A duplicate blank determination should be made on each batch received, and the average subtracted from the extraction results. Since the blank values are relatively small (0.5 mg/150 ml hexane to 3.0 mg/150 ml hexane) and easily corrected for, it will, in most cases, be unnecessary to use the expensive analytical grade hexane.

Rising Sludge: Sludge may rise in some samples and clog the glass filter paper. This occurs mainly in samples containing a high concentration of suspended solids and is most easily prevented by diluting the samples 1:1 with distilled water before preheating. (Too violent mixing will have the same effect).

APPENDIX B

LABORATORY DETERMINATION OF FLOATABLE MATERIAL IN SEWAGE

GENERAL DISCUSSION

Principle: The floatable material in a sewage sample is concentrated on the surface of the sample in a special Teflon coated Flotation Funnel. The remainder of the sample is drained off and the floatable material collected, washed, and weighed on a glass filter paper. The hexane extractable fraction of the floatable material can be determined subsequently by cutting the filter paper into 1 cm x 1 cm pieces and extracting these.

APPARATUS

Flotation Funnel: A Teflon coated 3-liter Flotation Funnel provided with a 7-mm bore Teflon stop cock is shown in Figure B-1. The Flotation Funnel should be provided with a 10 ml, 40 ml, 200 ml, and 3000 ml mark.

Mixer: Variable speed paddle mixer adjustable from 40 RPM to 100 RPM.

Paddle: Teflon coated brass paddle 75 mm x 25 mm.

Filter Holder: Teflon coated Millipore filter holders. Catalog No. XX 10 047 00.

Filter Papers: Whatman GF/c. 5.5 cm

Suction Flask

Vacuum Pump

Oven: Adjusted to between 35° C and 40° C.

Cleaning Rod: A 3 mm diameter Teflon coated brass rod 85 cm long.

PROCEDURE

Sample Collection and Preparation

Collect an 8-liter sample in a bucket provided with a bottom outlet. Great care must be taken to sample at points where the waste stream is completely mixed. Best results are obtained when the bucket is dipped directly into the waste stream. Transport the 8-liter sample to the laboratory, place a propeller stirrer in the bucket and stir so floatables are thoroughly mixed throughout the whole 8-liter volume. While stirring, transfer three liters through the bottom outlet into the Flotation Funnel. The sample shall be transferred to the Flotation Funnel within two hours after collection to insure that no significant change in the amount of floatable material takes place.

Place the Flotation Funnel in a rack and fasten securely to prevent even slight movements.

Conduct the test at the same temperature as that of the receiving body of water.

Correction for Density and for Concentration Effects

When a waste to be analyzed is being discharged into a receiving water with a density and ion concentration different from that of waste itself, the density and ion concentration of the waste should be adjusted to that of the receiving water. In the frequent case where the receiving water is ocean water, the density adjustment should be done in the following manner: 1.5 l sample is placed in the Flotation Funnel and 1.5 l filtered sea water for the receiving area added together with mixture of 39.8 NaCl, 8.0 g $MgCl_2$-$6H_2O$, 10.1 g $MgSO_4$-$7H_2O$, and 2.3 g $CaCl_2$-$2H_2O$. The final mixture will then contain 1.5 l sample in a medium of the approximately same density and ion concentration as sea water.

Mixing and Flotation

Place the paddle mixer in the Flotation Funnel, mix, settle, and discharge as shown in Table B-1. It is important that the surface of the sample in the Flotation Funnel remains undisturbed during the discharge to prevent loss of floatables. The discharge rate shall be 500 ml per minute except for the last 30 ml which shall be discharged dropwise.

Filtration and Weighing

Place a washed, dried, and weighed glass filter paper in the Teflon coated filter holder and filter the last 10 ml with the floatable material. Wash with distilled water. An additional piece of preweighed filter paper may be used to wipe the bottom of the filter holder if necessary.

Dry the filter (and the additional piece if used) at 35° C or 40° C for 1-1/2 hours, place in a desiccator for 15 minutes and weigh. Redry to constant weight.

CALCULATIONS

$$\text{mg/l Floatable Material} = \frac{\text{mg/increase in weight of filter}}{\text{volume of sample in liters}}$$

PRECISION AND ACCURACY

Replicate analysis of sewage samples as shown in Table B-II, showed the following standard deviations and recoveries:

TABLE B-I

MIXING AND FLOTATION SCHEDULE

1. Mix at 40 RPM for 15 minutes.
2. Let settle 5 minutes.
3. Mix at 100 RPM for 1 minute.
4. Let settle 30 minutes.
5. Discharge 2.8 liters at a rate of 500 ml/min. (Use cleaning rod if settled material clogs the stop cock).
6. Wash mixing paddle and sides of the Flotation Funnel with distilled water from a wash bottle until all particulate matter has moved to the bottom of the funnel.
7. Let settle 15 minutes.
8. Discharge down to the 40 ml mark.
9. Let settle 10 minutes.
10. Discharge dropwise to the 10 ml mark.
11. *Add 500 ml distilled water of same temperature as the sample, and repeat steps seven through ten.

*Step 11 can be omitted for samples containing high concentrations of floatable material and low concentrations of suspended solids.

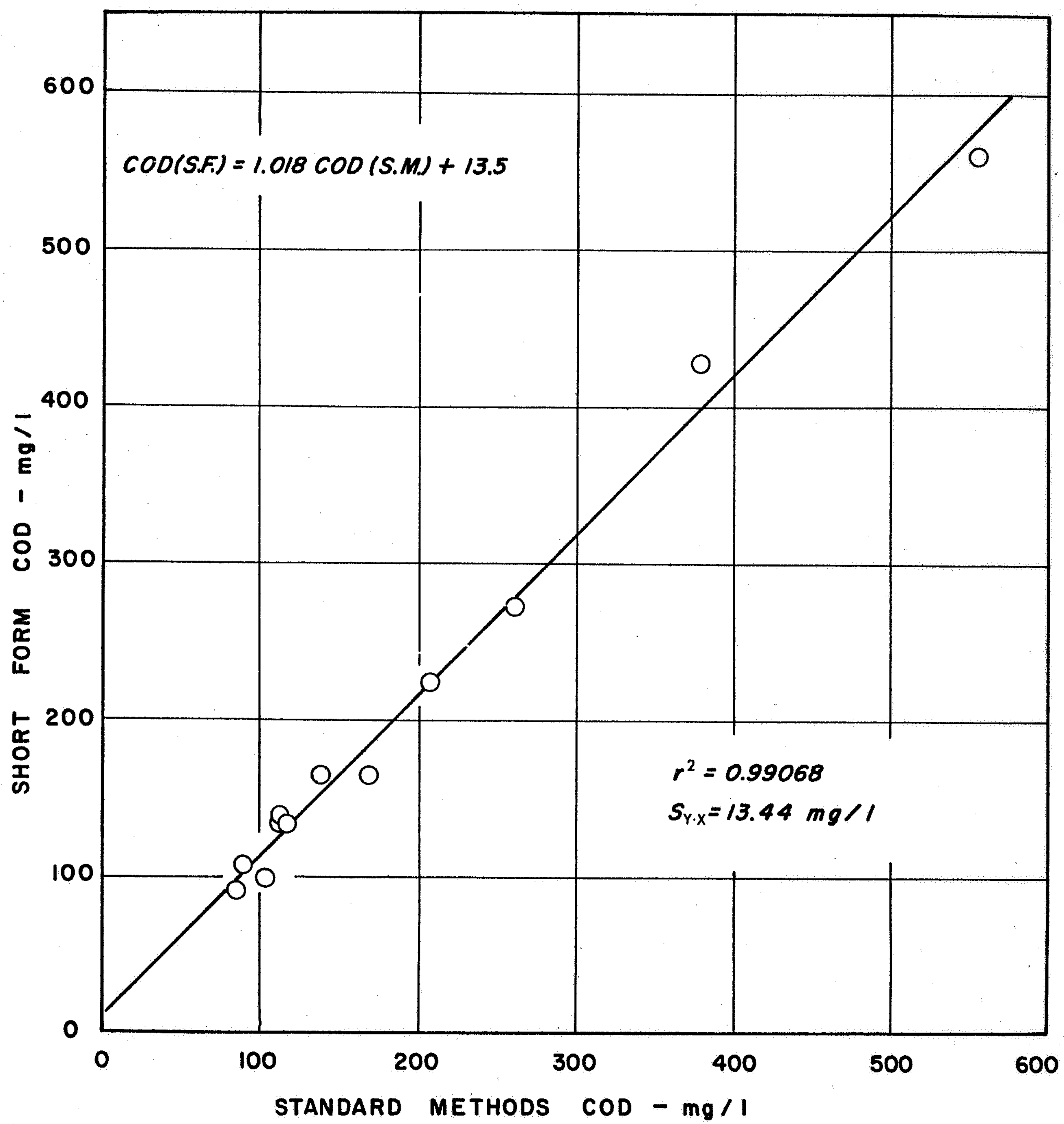
TABLE B-II

PRECISION AND ACCURACY OF THE FLOATABLES DETERMINATION METHOD

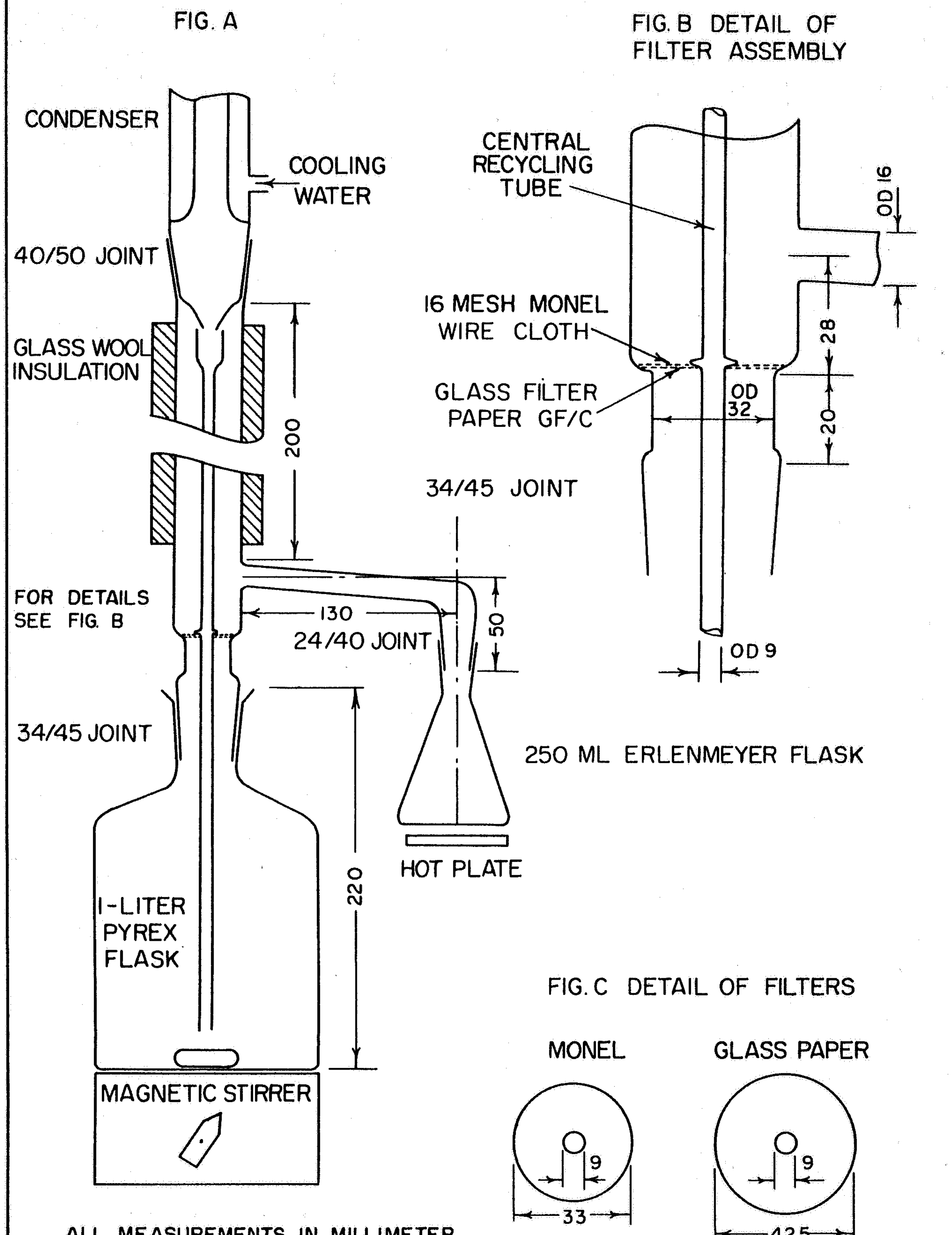
Type of Sewage	Avg. Floatables Concentration mg/l	No of Samples	Coef. of Variation	Percent Recovery
Raw*	49. mg/l	5	5.7%	96%
Raw	1.0 mg/l	5	20%	92%
Primary Effluent	2.7 mg/l	5	15%	91%

*) Additional floatable material added from skimmings from a primary tank.

CORRELATION BETWEEN SHORT FORM C.O.D. AND STANDARD METHODS C.O.D.



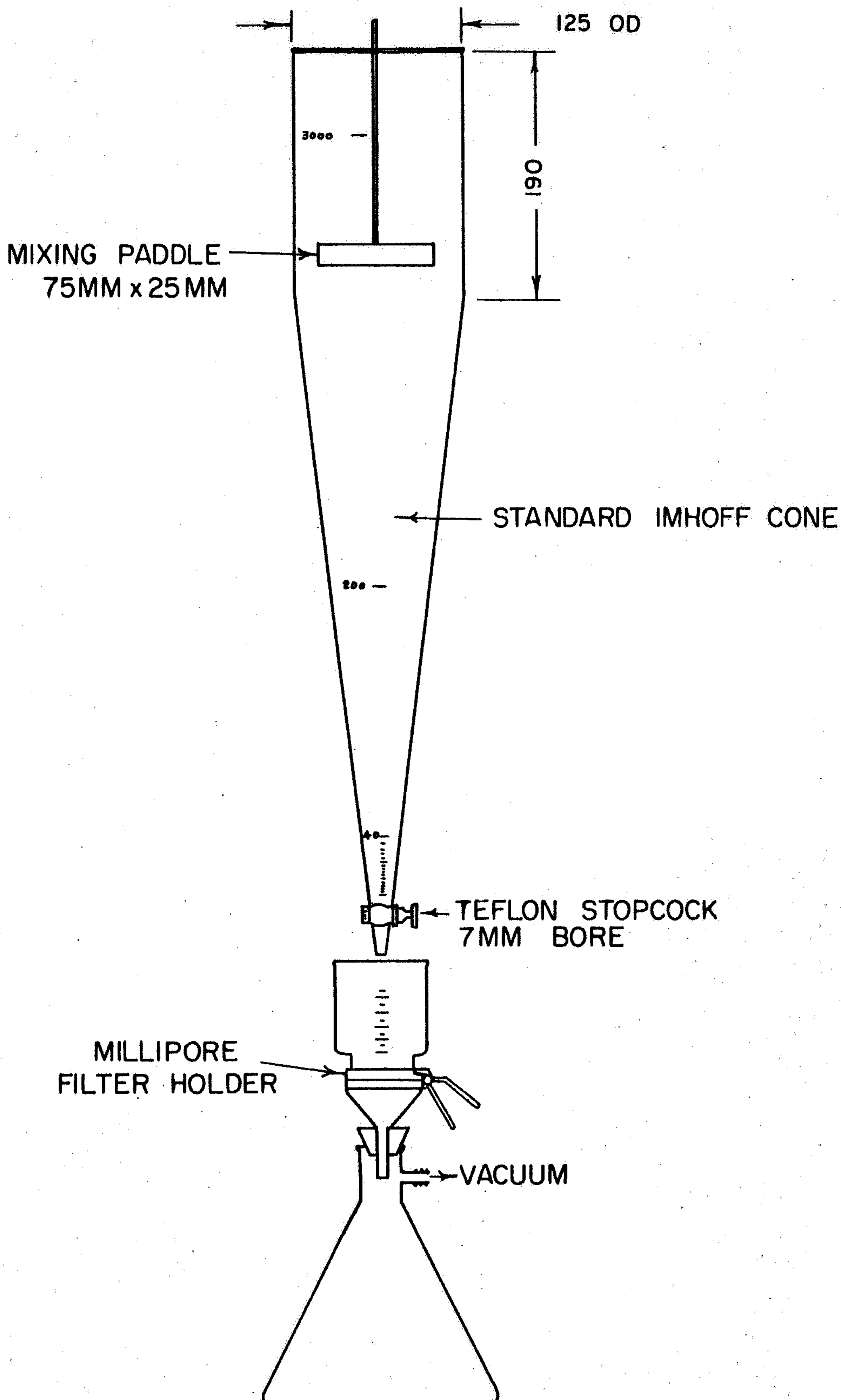
PEARSON - THOMAS EXTRACTOR



ALL MEASUREMENTS IN MILLIMETER

FIGURE B - 3

FLOTATION FUNNEL



ALL MEASUREMENT IN MILLIMETER

APPENDIX C

DRY WEATHER MONITORING DATA

TREATMENT OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

DRY WEATHER MONITORING RESULTS

SELBY STREET OUTFALL
6 September 1966

SAMPLE TIME	1 0030	2 0310	3 0600	4 0900	5 1155	6 1420	7 1743	8 2050
TEMPERATURE, °C	22	21	20	21	20	22	21.5	22
pH	7.5	7.7	7.6	8.0	7.4	7.4	7.6	7.6
CONDUCTIVITY, µmho/cm	720	820	780	940	700	695	720	685
ALKALINITY, mg/l as $CaCO_3$	204	204	190	302	194	178	188	180
SUSPENDED SOLIDS, mg/l	73	63	45	270	264	208	164	250
VOLATILE SUSPENDED SOLIDS, mg/l	26	37	46	210	188	152	121	199
GREASE, mg/l	32	11	6	61	-	92	54	115
COD, mg/l	239	226	110	580	467	525	408	634
BOD, mg/l	140	40*	-	198	225	245	182	189
FLOATABLE PARTICULATES, mg/l	1.7	4.3	6.3	3.9	12.0	-	2.4	3.7
SETTLEABLE SOLIDS @ 30 Min., ml/l	-	-	-	-	-	-	-	-
TOTAL KJELDAHL NITROGEN, mg/l -N	23.0	10.7	-	-	-	-	-	-
AMMONIA NITROGEN, mg/l -N	20.2	9.0	9.5	-	-	-	-	-
TOTAL PHOSPHATE, mg/l PO_4	7.2	4.2	2.3	1.8	15.7	17.3	12.5	10.5
SULFATE, mg/l	20	20	20	14	22	24	22	14
CHLORIDE, mg/l	75	110	95	75	60	65	72	60
SODIUM, mg/l	55	68.5	62	59	67.5	72	66.5	61
POTASSIUM, mg/l	9.6	7.2	6.1	13.7	8.6	9.2	9.7	13.4
CALCIUM, mg/l	24	32	34	18	12	24	24	18
MAGNESIUM, mg/l	14.6	17	18.2	15.8	17	12.2	14.6	10.9

* 20%-30% D.O. Depletion

TREATMENT OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

DRY WEATHER MONITORING RESULTS

SELBY STREET OUTFALL
17-18 September 1966

SAMPLE TIME	1 2115	2 0015	3 0315	4 0620				
TEMPERATURE, °C	22.5	21.8	21.5	21.0				
pH	7.4	7.6	7.7	7.5				
CONDUCTIVITY, µmho/cm	580	555	700	750				
ALKALINITY, mg/l as $CaCO_3$	136	151	170	112				
SUSPENDED SOLIDS, mg/l	280	346	112	57				
VOLATILE SUSPENDED SOLIDS, mg/l	228	274	95	42				
GREASE, mg/l	-	-	-	-				
COD, mg/l	690	695	187	195				
BOD, mg/l	282	203	59*	43**				
FLOATABLE PARTICULATES, mg/l	3.8	6.1	3.5	2.9	-----------Rain-----------			
SETTLEABLE SOLIDS @ 30 Min., ml/l	10	12	5	2				
TOTAL KJELDAHL NITROGEN, mg/l -N	28.6	27.5	16.2	34.2				
AMMONIA NITROGEN, mg/l -N	-	-	-	-				
TOTAL PHOSPHATE, mg/l PO_4	4	4.7	3.4	1.2				
SULFATE, mg/l	24	18	20	38				
CHLORIDE, mg/l	55	65	70	105				
SODIUM, mg/l	52	50	52	66				
POTASSIUM, mg/l	11.2	9.4	8.5	6.7				
CALCIUM, mg/l	20	22	30	36				
MAGNESIUM, mg/l	13.4	15.8	18.2	17				

* 30%-40% D.O. Depletion
** 20%-30% D.O. Depletion

TREATMENT OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

DRY WEATHER MONITORING RESULTS

SELBY STREET OUTFALL
21 September 1966

SAMPLE TIME	1 0000	2 0305	3 0610	4 0847	5 1200	6 1530	7 1800	8 2100
TEMPERATURE, °C	-	21.5	21.0	21.5	23.0	22.0	22.0	-
pH	7.6	7.6	7.5	7.8	7.5	7.5	7.5	7.4
CONDUCTIVITY, umho/cm	590	740	740	740	700	700	695	620
ALKALINITY, mg/l as $CaCO_3$	169	201	181	314	176	167	167	154
SUSPENDED SOLIDS, mg/l	135	85	28	340	586	188	190	258
VOLATILE SUSPENDED SOLIDS, mg/l	109	61	18	246	-	132	-	216
GREASE, mg/l	23.9	8.4	4.8	53.4	51.9	26.8	35.2	67.3
COD, mg/l	376	219	158	780	665	482	575	760
BOD, mg/l	144	49*	-	207	146	112	173	222
FLOATABLE PARTICULATES, mg/l	5.4	4.2	1.5	11.8	3.9	4.3	1.4	3.8
SETTLEABLE SOLIDS @ 30 Min., ml/l	7	2	0	17	8	6	-	-
TOTAL KJELDAHL NITROGEN, mg/l -N	37.0	23.5	20.7	76.7	33.6	28.6	36.4	36.4
AMMONIA NITROGEN, mg/l -N	-	-	-	-	-	-	-	-
TOTAL PHOSPHATE, mg/l PO_4	7.1	3.8	2.4	8.1	13.6	11.1	10.3	9
SULFATE, mg/l	20	16	20	20	36	32	32	28
CHLORIDE, mg/l	68	90	100	75	68	70	68	65
SODIUM, mg/l	56.5	62	69	58	80	74	70	60
POTASSIUM, mg/l	9.6	7.6	6.6	13.8	9.9	12.8	14	13.5
CALCIUM, mg/l	24	30	36	26	23	22	25.2	10
MAGNESIUM, mg/l	9.7	14.6	19.4	11.7	11.7	13.4	10.2	4.9

*30%-40% D.O. Depletion

TREATMENT OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

DRY WEATHER MONITORING RESULTS

SELBY STREET OUTFALL
23-24 September 1966

SAMPLE TIME	1 2230	2 0130	3 0430	4 0730	5 1022	6 1350	7 1630	8 1930
TEMPERATURE, °C	22	21.5	21	21	21.5	23.5	23.5	22
pH	7.6	7.7	7.8	7.8	8.3	7.3	7.5	7.5
CONDUCTIVITY, umho/cm	480	525	570	590	625	485	470	460
ALKALINITY, mg/l as $CaCO_3$	165	197	192	185	270	167	161	152
SUSPENDED SOLIDS, mg/l	171	120	142	73	374	214	175	197
VOLATILE SUSPENDED SOLIDS, mg/l	139	95	99	44	286	179	139	165
GREASE, mg/l	29.6	27.9	3.9	3.7	28.8	23.7	27.9	67.7
COD, mg/l	645	310	212	159	694	531	347	587
BOD, mg/l	188	96	38**	-	254	218	170*	218
FLOATABLE PARTICULATES, mg/l	3.2	1.7	0.4	1.3	4.6	3.6	2.7	4.0
SETTLEABLE SOLIDS @ 30 Min., ml/l	-	-	-	2	16	9	-	-
TOTAL KJELDAHL NITROGEN, mg/l -N	42.5	37.0	21.8	20.7	71.6	27.5	24.7	28.6
AMMONIA NITROGEN, mg/l -N	-	-	-	-	-	-	-	-
TOTAL PHOSPHATE, mg/l PO_4	8.3	4.5	1.9	1.5	9.6	16.2	12	9.4
SULFATE, mg/l	24	22	22	24	20	40	32	24
CHLORIDE, mg/l	68	70	100	105	70	58	58	60
SODIUM, mg/l	63.5	63.5	65.5	67	60.5	77	70.5	60.5
POTASSIUM, mg/l	10.8	10.0	8.5	7.2	14.3	10.8	10.8	10.6
CALCIUM, mg/l	20.8	24	36	38	26.8	20	22	24
MAGNESIUM, mg/l	9.7	14.6	14.6	17	9.7	9.7	10.9	10.9

* 30%-40% D.O. Depletion
** 20%-30% D.O. Depletion

TREATMENT OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

DRY WEATHER MONITORING RESULTS

SELBY STREET OUTFALL
26-27 September 1966

SAMPLE TIME	1 2113	2 0020	3 0300	4 0620	5 0920	6 1215	7 1515	8 1815
TEMPERATURE, °C	22.5	22.0	22.0	21.0	22.0	22.5	23.5	22.5
pH	7.6	8.0	8.1	8.0	8.9	7.7	7.5	7.6
CONDUCTIVITY, umho/cm	455	490	560	575	665	490	470	495
ALKALINITY, mg/l as $CaCO_3$	172	177	203	183	310	182	167	155
SUSPENDED SOLIDS, mg/l	160	242	71	32	298	224	242	127
VOLATILE SUSPENDED SOLIDS, mg/l	131	192	49	22	230	168	160	76
GREASE, mg/l	59.6	23.1	10.1	5.9	22.4	34.5	38.4	29.3
COD, mg/l	682	379	257	159	575	612	453	433
BOD, mg/l	224	170	69*	-	213	213	173	170
FLOATABLE PARTICULATES, mg/l	0.6	0.8	0.3	0.1	0.8	1.0	0.9	1.3
SETTLEABLE SOLIDS @ 30 Min., ml/l	8	8	4	1	15	8	7	6
TOTAL KJELDAHL NITROGEN, mg/l -N	25.2	30.8	32.5	18.5	76.9	31.9	21.8	28.6
AMMONIA NITROGEN, mg/l -N	15.7	20.2	14.0	11.2	59.5	14.6	11.7	16.3
TOTAL PHOSPHATE, mg/l PO_4	9	6.6	3	5.7	7	13.4	10.5	9.2
SULFATE, mg/l	24	24	22	24	210	48	30	30
CHLORIDE, mg/l	30	60	85	90	60	50	53	60
SODIUM, mg/l	60.5	57	63	65	50	77	72	70
POTASSIUM, mg/l	12.5	11.4	9.1	7.3	17.3	10	12	11.6
CALCIUM, mg/l	12	24	34	36	24	20	21.2	24
MAGNESIUM, mg/l	3.7	9.7	18.2	21.9	9.7	11.7	11.9	10.9

* 30%-40% D.O. Depletion

TREATMENT OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

DRY WEATHER MONITORING RESULTS

SELBY STREET OUTFALL
2-3 October 1966

SAMPLE TIME	1 2100	2 2230	3 0005	4 0130	5 0300	6 0430	7 0600	8 0730
TEMPERATURE, °C	22	22	22	22	21.5	21	21	21
pH	7.3	7.2	7.8	7.8	7.8	7.6	7.7	7.7
CONDUCTIVITY, µmho/cm	700	640	730	770	800	780	820	770
ALKALINITY, mg/l as $CaCO_3$	177	175	188	204	203	191	193	198
SUSPENDED SOLIDS, mg/l	262	226	239	169	103	51	36	63
VOLATILE SUSPENDED SOLIDS, mg/l	200	178	191	136	69	34	20	49
GREASE, mg/l	45.9	50.9	28.0	17.3	15.0	5.3	5.6	5.3
COD, mg/l	555	734	611	245	-	131	114	131
BOD, mg/l	316	282	151	131	59	35*	31*	48**
FLOATABLE PARTICULATES, mg/l	1.5	5.1	1.6	0.8	1.0	1.3	0.6	1.0
SETTLEABLE SOLIDS @ 30 Min., ml/l	7	8	9	9	3	2	2	4
TOTAL KJELDAHL NITROGEN, mg/l -N	31.4	29.1	31.9	34.2	25.2	18.6	18.9	21.9
AMMONIA NITROGEN, mg/l -N	17.9	19.0	19.6	22.4	16.2	13.5	13.5	15.7
TOTAL PHOSPHATE, mg/l PO_4	7.0	7.0	5.9	5.1	3.4	2.4	2.2	2.1
SULFATE, mg/l	26	24	22	20	22	24	24	24
CHLORIDE, mg/l	80	75	80	85	100	110	115	105
SODIUM, mg/l	55	61	55	57	62	64.5	63.5	61
POTASSIUM, mg/l	12	10.4	10.4	10.4	8.6	7.8	7.2	7.4
CALCIUM, mg/l	20	22	26	24	32	32	36	34
MAGNESIUM, mg/l	15.8	12.2	10.9	13.4	20.6	2.5	24.3	19.5

* 30%-40% D.O. Depletion
** 20%-30% D.O. Depletion

TREATMENT OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

DRY WEATHER MONITORING RESULTS

SELBY STREET OUTFALL (Cont'd)
2-3 October 1966

SAMPLE TIME	9 0855	10 1030	11 1645	12 1800	13 1930			
TEMPERATURE, °C	21	22	23.5	22	22			
pH	8.45	8.15	7.6	7.7	7.8			
CONDUCTIVITY, umho/cm	780	780	700	700	670			
ALKALINITY, mg/l as $CaCO_3$	290	240	182	192	171			
SUSPENDED SOLIDS, mg/l	398	298	259	200	199			
VOLATILE SUSPENDED SOLIDS, mg/l	328	254	206	181	181			
GREASE, mg/l	19.9	25.5	47.7	28.7	42.0			
COD, mg/l	694	559	587	546	616			
BOD, mg/l	267	216	187	176	204			
FLOATABLE PARTICULATES, mg/l	2.7	0.7	0.9	1.4	1.4			
SETTLEABLE SOLIDS @ 30 Min., ml/l	13	13	9	8	8			
TOTAL KJELDAHL NITROGEN, mg/l -N	70.6	52.1	26.8	24.6	30.9			
AMMONIA NITROGEN, mg/l -N	45.4	33.0	12.3	15.1	16.2			
TOTAL PHOSPHATE, mg/l PO_4	6.6	10.8	11.0	9.9	11.5			
SULFATE, mg/l	34	38	34	36	34			
CHLORIDE, mg/l	75	75	80	80	75			
SODIUM, mg/l	48	67.5	75	72	71			
POTASSIUM, mg/l	13	11.8	10.7	11.4	14.4			
CALCIUM, mg/l	24	24	22	24	26			
MAGNESIUM, mg/l	14.6	13.4	17	12.2	9.7			

TREATMENT OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

DRY WEATHER MONITORING RESULTS

LAGUNA STREET OUTFALL
6 September 1966

SAMPLE TIME	1 0140	2 0445	3 0730	4 1030	5 1300	6 1625	7 1930	8 2230
TEMPERATURE, °C	22	22	23.5	25.5	24	25	28	24
pH	7.9	7.8	8.2	7.1	7.5	7.3	7.4	7.7
CONDUCTIVITY, μmho/cm	470	495	655	890	515	520	515	440
ALKALINITY, mg/l as $CaCO_3$	162	176	234	150	146	138	146	148
SUSPENDED SOLIDS, mg/l	99	33	302	197	233	219	125	130
VOLATILE SUSPENDED SOLIDS, mg/l	66	19	242	159	180	159	119	108
GREASE, mg/l	13	9	-	57	106	64	101	54
COD, mg/l	185	160	497	467	525	351	471	(445)
BOD, mg/l	57	32	186	166	248	188	196	173
FLOATABLE PARTICULATES, mg/l	5.3	3.6	2.9	0.6	4.3	1.2	3.0	2.6
SETTLEABLE SOLIDS @ 30 Min., ml/l	-	-	-	-	-	-	-	-
TOTAL KJELDAHL NITROGEN, mg/l -N	23.5	-	-	-	-	-	-	-
AMMONIA NITROGEN, mg/l -N	21.3	-	-	-	-	-	-	-
TOTAL PHOSPHATE, mg/l PO_4	2.8	2.7	7.8	10.5	11	11	19.8	7.1
SULFATE, mg/l	18	10	10	22	18	16	22	16
CHLORIDE, mg/l	30	20	30	140	52	50	35	35
SODIUM, mg/l	20.5	20.5	25	108	60.5	50	48.5	27
POTASSIUM, mg/l	7	6.2	9	8	7.9	8.7	8.2	8
CALCIUM, mg/l	16	24	12	10	14	16	20	-
MAGNESIUM, mg/l	7.3	9.7	9.7	10.9	9.7	3.7	7.3	-

* Partial Sector

TREATMENT OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

DRY WEATHER MONITORING RESULTS

LAGUNA STREET OUTFALL *
8-9 September 1966

SAMPLE TIME	1 2230	2 0130	3 0430	4 0730	5 1030	6 1330	7 1630	8 1930
TEMPERATURE, °C	25	23.5	22	23	26	26	25	25
pH	7.4	7.3	7.4	8.1	8.0	7.6	7.6	7.4
CONDUCTIVITY, µmho/cm	295	285	325	500	545	505	435	440
ALKALINITY, mg/l as $CaCO_3$	148	153	158	258	134	139	125	136
SUSPENDED SOLIDS, mg/l	342	105	55	266	230	219	143	210
VOLATILE SUSPENDED SOLIDS, mg/l	296	82	40	214	208	174	124	168
GREASE, mg/l	-	23	11	45	37	86	53	96
COD, mg/l	(555)	216	112	449	433	392	299	474
BOD, mg/l	222	127	(21)	202	237	242	169	277
FLOATABLE PARTICULATES, mg/l	4.9	2.9	0.7	2.1	1.9	1.7	2.0	2.8
SETTLEABLE SOLIDS @ 30 Min., ml/l	-	-	-	-	-	-	-	-
TOTAL KJELDAHL NITROGEN, mg/l -N	25.2	26.9	19.1	56.6	28.6	18.4	20.7	23.6
AMMONIA NITROGEN, mg/l -N	18.5	-	-	-	-	-	-	-
TOTAL PHOSPHATE, mg/l PO_4								
SULFATE, mg/l								
CHLORIDE, mg/l								
SODIUM, mg/l				No Data				
POTASSIUM, mg/l								
CALCIUM, mg/l								
MAGNESIUM, mg/l								

* Partial Sector

TREATMENT OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

DRY WEATHER MONITORING RESULTS

LAGUNA STREET OUTFALL *
11-12 September 1966

SAMPLE TIME	1 2235	2 0130	3 0430	4 0735	5 1030	6 1330	7 1630	8 1930
TEMPERATURE, °C	24.5	23	22	23.5	26.5	25.5	25	26
pH	5.8	7.5	7.4	8.0	8.3	7.9	7.6	7.6
CONDUCTIVITY, µmho/cm	458	395	373	480	495	420	410	462
ALKALINITY, mg/l as $CaCO_3$	52	143	142	208	141	125	134	138
SUSPENDED SOLIDS, mg/l	184	92	44	380	186	198	222	260
VOLATILE SUSPENDED SOLIDS, mg/l	164	78	36	320	162	180	194	244
GREASE, mg/l	41	11	6	30	56	83	42	81
COD, mg/l	560	167	146	550	515	480	425	730
BOD, mg/l	197	80	(37)	202	208	211	144	280
FLOATABLE PARTICULATES, mg/l	9.0	1.6	2.1	1.5	3.1	3.7	2.8	3.4
SETTLEABLE SOLIDS @ 30 Min., ml/l	-	-	-	-	10	11	12	-
TOTAL KJELDAHL NITROGEN, mg/l -N	33.0	26.9	25.2	63.7	26.3	20.7	29.7	29.7
AMMONIA NITROGEN, mg/l -N	-	-	-	-	-	-	-	-
TOTAL PHOSPHATE, mg/l PO_4								
SULFATE, mg/l								
CHLORIDE, mg/l								
SODIUM, mg/l	----------	----------	----------	----------	---No Data---	----------	----------	----------
POTASSIUM, mg/l								
CALCIUM, mg/l								
MAGNESIUM, mg/l								

* Partial Sector

TREATMENT OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

DRY WEATHER MONITORING RESULTS

LAGUNA STREET OUTFALL
17-18 September 1966

SAMPLE TIME	1 2300	2 0150	3 0450	4 0750	5 1020	6 1320	7 1615	8 1930
TEMPERATURE, °C	24.5	24	23.5	19	24.5	26	25	25
pH	7.6	7.9	7.6	7.1	7.9	7.6	7.8	7.5
CONDUCTIVITY, umho/cm	440	385	360	252	800	359	361	360
ALKALINITY, mg/l as $CaCO_3$	111	113	104	26	137	92	103	96
SUSPENDED SOLIDS, mg/l	206	111	73	338	222	211	169	216
VOLATILE SUSPENDED SOLIDS, mg/l	186	97	67	256	210	192	157	205
GREASE, mg/l	59	19	52	59	53	83	55	99
COD, mg/l	445	230	145	325	570	625	450	585
BOD, mg/l	200	87	57	69	192	234	152	234
FLOATABLE PARTICULATES, mg/l	7.5	4.1	8.5	2.7	3.9	4.2	2.2	7.4
SETTLEABLE SOLIDS @ 30 Min., ml/l	10	8	7	4	14	11	10	9
TOTAL KJELDAHL NITROGEN, mg/l -N	33.0	34.2	24.1	14.6	40.8	27.5	23.5	28.0
AMMONIA NITROGEN, mg/l -N	-	-	-	-	-	-	-	-
TOTAL PHOSPHATE, mg/l PO_4	5.6	2.9	1.4	0.4	6.5	8.2	8.5	5.4
SULFATE, mg/l	16	10	10	16	18	22	20	16
CHLORIDE, mg/l	35	25	20	35	155	40	35	45
SODIUM, mg/l	38	19.5	17	19	110	42.5	42.5	38
POTASSIUM, mg/l	9.2	7.5	5.6	4.2	12.8	8.5	9.9	10
CALCIUM, mg/l	12	16	16	16	12	10	12	10
MAGNESIUM, mg/l	9.7	3.7	7.3	2.4	6.1	9.7	7.3	8.5

TREATMENT OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

DRY WEATHER MONITORING RESULTS

LAGUNA STREET OUTFALL
20-21 September 1966

SAMPLE TIME	1 2230	2 0115	3 0450	4 0730	5 1030	6 1330	7 1640	8 1930
TEMPERATURE, °C	-	24	23	24	27	26	25	25
pH	7.6	7.6	7.9	8.4	7.5	8.1	7.9	7.6
CONDUCTIVITY, μmho/cm	345	340	320	420	500	410	460	370
ALKALINITY, mg/l as $CaCO_3$	121	119	120	209	135	122	119	124
SUSPENDED SOLIDS, mg/l	158	83	29	258	238	155	172	232
VOLATILE SUSPENDED SOLIDS, mg/l	123	72	24	214	188	123	138	192
GREASE, mg/l	19.7	9.1	3.9	25.7	34.1	20.5	26.1	33.9
COD, mg/l	421	235	113	563	515	417	417	725
BOD, mg/l	173	81	21	207	156	128	126	297
FLOATABLE PARTICULATES, mg/l	6.3	2.4	1.1	3.3	2.8	0.5	2.3	2.1
SETTLEABLE SOLIDS @ 30 Min., ml/l	10	7	-	19	12	9	-	-
TOTAL KJELDAHL NITROGEN, mg/l -N	32.4	28.0	24.0	67.1	29.1	25.2	27.5	33.0
AMMONIA NITROGEN, mg/l -N	-	-	-	-	-	-	-	-
TOTAL PHOSPHATE, mg/l PO_4	6.7	2.7	2.3	5.2	8.1	7.7	4.5	5.2
SULFATE, mg/l	20	14	12	16	22	20	16	16
CHLORIDE, mg/l	25	20	18	25	68	35	30	28
SODIUM, mg/l	70	38	17.5	29	85	52	42	35
POTASSIUM, mg/l	9.5	7.5	6	10.8	9.6	10.6	9.5	9.4
CALCIUM, mg/l	14	14.8	14	14	13.2	10	12	14
MAGNESIUM, mg/l	4.9	4.9	5.6	4.9	3.7	2.2	2.4	6.1

TREATMENT OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

DRY WEATHER MONITORING RESULTS

LAGUNA STREET OUTFALL
23-24 September 1966

SAMPLE TIME	1 2125	2 0000	3 0300	4 0600	5 0850	6 1200	7 1515	8 1810
TEMPERATURE, °C	25	24.5	23.5	23	24	26	25.5	25.5
pH	7.5	7.8	7.9	8.1	8.1	7.5	7.5	7.3
CONDUCTIVITY, umho/cm	350	370	330	368	510	370	370	368
ALKALINITY, mg/l as $CaCO_3$	110	128	121	143	195	104	106	87
SUSPENDED SOLIDS, mg/l	192	116	76	85	298	184	161	194
VOLATILE SUSPENDED SOLIDS, mg/l	174	101	70	74	246	156	145	190
GREASE, mg/l	56.6	2.5	3.9	6.6	23.6	29.9	24.9	39.6
COD, mg/l	633	359	147	167	518	470	408	518
BOD, mg/l	232	115	56*	54*	212	194	188	254
FLOATABLE PARTICULATES, mg/l	1.6	2.8	0.8	0.8	2.1	1.9	2.4	4.2
SETTLEABLE SOLIDS @ 30 Min., ml/l	-	-	-	7	18	10	-	-
TOTAL KJELDAHL NITROGEN, mg/l -N	27.4	29.7	26.4	28.6	56.6	24.1	28.0	30.2
AMMONIA NITROGEN, mg/l -N	-	-	-	-	-	-	-	-
TOTAL PHOSPHATE, mg/l PO_4	5.5	5.2	1.6	2.4	5.9	9.6	7.5	7
SULFATE, mg/l	16	16	10	10	14	22	22	18
CHLORIDE, mg/l	25	25	20	23	33	33	35	33
SODIUM, mg/l	32.5	32.5	17	18	32.5	46	43.5	38
POTASSIUM, mg/l	9.3	6.5	5.3	5.5	9.6	8	8.2	8.1
CALCIUM, mg/l	12	10.8	16	16	12	12	10	12
MAGNESIUM, mg/l	7	4.4	4.4	7.3	4.9	2.4	7.3	7.3

* 30%-40% D.O. Depletion

DRY WEATHER COLIFORM MPN's - SELBY STREET

Time	Confirmed, $x10^4$ MPN/ml			Fecal, $x10^4$ MPN/ml		
	13 June 1967	1 August 1967	Log Mean	13 June 1967	1 August 1967	Log Mean
700	6	6	6	≤ 2.3	6	3.72
830	62	240	122	23	62	37.8
1000	62	23	37.8	13	23	17.3
1130	23	23	23	23	23	23
1300	23	62	37.8	23	62	37.8
1430	62	6	19.3	6	6	6
1600	62	23	37.8	23	6	11.75
1730	62	62	62	6	62	19.3
1900	130	23	54.7	6	6	6
2030	23	62	37.8	6	62	19.3
2200	130	130	130	13	62	28.4
2330	23	62	37.8	≤ 2.3	23	7.3
0100	≥ 240	62	122	6.2	23	11.93
0230	23	70	40.1	6.2	70	20.8
0400	23	≥ 240	74.3	6.2	24	12.2
0530	6	70	20.5	6.2	70	20.8

DRY WEATHER COLIFORM MPN's - LAGUNA STREET

Time	Confirmed, x10^4 ml			Fecal, x10^4 MPN/ml		
	20 Dec 1967	17 Jan 1967	Log Mean	20 Dec 1967	20 Jan 1967	Log Mean
600	23	62	38	< 2.3	6	6.0
710	23	700	126	6	13	9.5
845	62	62	62	23	23	2.3
1005	240	62	120	4.6	62	1.7
1155	240	50	103	< 2.3	23	6.8
1300	62	62	62	6	6	6.0
1450	62	21	26	13	< 2.3	5.0
1610	23	62	38	6	< 2.3	3.5
1755	240	23	74	6	< 2.3	3.5
1900	23	50	34	6	6	6.0
2115	240	240	240	< 6	4.6	3.0
2200	-	62	62	-	6.0	6.0
0000	62	6.0	20	< 6	6.0	3.5
0105	4.6	6.0	5.3	4.6	< 2.3	3.0
0300	62	≤ 2.3	11	6	< 2.3	3.5
0400	23	23	23	6	< 2.3	3.5

APPENDIX D

WET WEATHER MONITORING DATA

TREATMENT OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

WET WEATHER MONITORING RESULTS
SELBY STREET OUTFALL (Cont'd)
6 November 1966

SAMPLE TIME	9 1154	10 1204	11 1214	12 1224	13 1244	14 1304	15 1324	16 1344
FLOW, cfs	575	727	690	590	396	303	165	80
COLIFORM MPN - Conf./Fecal, 10^4/ml								
CONDUCTIVITY, μmho/cm	90	86	77	67	69	91	139	229
ALKALINITY, mg/l as $CaCO_3$	25	23	21	17	17	18	18	18
SUSPENDED SOLIDS, mg/l	412	432	440	398	264	162	122	80
VOLATILE SUSPENDED SOLIDS, mg/l	168	162	136	110	78	46	46	26
GREASE, mg/l	51.9	43.9	48.7	24.6	9.2	6.6	10.5	5.2
COD, mg/l	408	350	268	239	173	168	144	165
BOD, mg/l	75	52	35	35	23	28	26	25
FLOATABLE PARTICULATES, mg/l	12.9	3.9	9.2	11.7	1.8	1.9	1.2	2.8
SETTLEABLE SOLIDS @ 30 Min., ml/l	6.3	4.0	4.3	3.3	0.7	1.0	<0.3	<0.3
TOTAL KJELDAHL NITROGEN, mg/l -N	7.4	15.8	5.3	8.4	5.6	4.6	3.9	3.2
AMMONIA NITROGEN, mg/l -N	0.7	1.4	0.7	0	0	0.4	1.1	0.4
TOTAL PHOSPHATE, mg/l PO_4	2.22	1.37	1.56	0.83	0.63	0.75	0.96	0.84
SULFATE, mg/l	24	18	22	20	24	20	50	26
CHLORIDE, mg/l								
SODIUM, mg/l	9.0	6.0	7.0	7.0	7.0	10.0	17.0	22.0
POTASSIUM, mg/l	1.8	2.2	1.5	1.3	1.5	1.2	2.1	2.7
CALCIUM, mg/l	16.0	15.2	14.4	8.8	7.2	8.0	8.0	12.0
MAGNESIUM, mg/l	3.89	2.92	0.97	0.49	0.49	0.9	0.97	1.94
SETTLED BOD, mg/l	32	32	30	26	16	14	15	19

TREATMENT OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

WET WEATHER MONITORING RESULTS
SELBY STREET OUTFALL (Cont'd)
6 November 1966

SAMPLE TIME	17 1404	18 1424	19 1454	20 1524				
FLOW, cfs	80	67	50	20				
COLIFORM MPN - Conf./Fecal, 10^4/ml								
CONDUCTIVITY, µmho/cm	192	128	99	118				
ALKALINITY, mg/l as $CaCO_3$	19	17	15	19				
SUSPENDED SOLIDS, mg/l	68	68	132	70				
VOLATILE SUSPENDED SOLIDS, mg/l	24	24	106	4				
GREASE, mg/l	2.0	4.3	16.8	9.2				
COD, mg/l	132	119	115	119				
BOD, mg/l	23	29	37	35				
FLOATABLE PARTICULATES, mg/l	2.1	2.1	2.5	2.4				
SETTLEABLE SOLIDS @ 30 Min., ml/l	<0.3	<0.3	1.3	<0.3				
TOTAL KJELDAHL NITROGEN, mg/l -N	2.6	3.2	3.5	3.5				
AMMONIA NITROGEN, mg/l -N	0	0.4	0.7	0				
TOTAL PHOSPHATE, mg/l PO_4	0.84	0.92	0.80	0.92				
SULFATE, mg/l	24	26	20	24				
CHLORIDE, mg/l								
SODIUM, mg/l	27.0	16.0	11.0	12.5				
POTASSIUM, mg/l	2.5	2.1	2.0	2.1				
CALCIUM, mg/l	11.2	8.0	7.2	8.0				
MAGNESIUM, mg/l	1.94	1.94	1.94	2.43				
SETTLED BOD, mg/l	13	20	20	19				

TREATMENT OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

WET WEATHER MONITORING RESULTS
SELBY STREET OUTFALL
15 November 1966

SAMPLE TIME	1 0635	2 0640	3 0645	4 0650	5 0700	6 0710	7 0720	8 0730
FLOW, cfs	105	170	150	130	90	90	70	90
COLIFORM MPN - Conf./Fecal, 10^4/ml								
CONDUCTIVITY, μmho/cm	245	212	232	220	420	415	375	270
ALKALINITY, mg/l as $CaCO_3$	43	42	53	78	107	106	95	69
SUSPENDED SOLIDS, mg/l	27	39	93	121	68	61	73	73
VOLATILE SUSPENDED SOLIDS, mg/l	14	25	51	69	40	36	33	31
GREASE, mg/l	1.8	8.2	7.3	6.3	4.5	0.4	3.9	5.2
COD, mg/l	142	146	187	256	142	138	199	122
BOD, mg/l	28	31	46	52	43	32	31	32
FLOATABLE PARTICULATES, mg/l	16	15	20	13	10	18	-	13
SETTLEABLE SOLIDS @ 30 Min., ml/l	<0.3	<0.3	1.7	1.0	<0.3	<0.3	-	<0.3
TOTAL KJELDAHL NITROGEN, mg/l -N	8.5	6.7	7.4	9.8	15.4	13.0	14.0	14.7
AMMONIA NITROGEN, mg/l -N	2.5	1.8	2.1	3.5	7.7	9.1	9.8	8.4
TOTAL PHOSPHATE, mg/l PO_4	1.24	1.05	1.16	1.64	1.32	1.78	1.74	1.34
SULFATE, mg/l	26	22	24	32	36	28	28	26
CHLORIDE, mg/l	33.2	28.2	14.4	34.4	52.5	40.6	23.6	16.6
SODIUM, mg/l	22.0	19.0	19.0	25.0	33.5	30.5	28.0	19.0
POTASSIUM, mg/l	3.7	3.2	3.2	3.7	4.5	4.0	4.0	4.0
CALCIUM, mg/l	14.4	15.6	20.4	28.8	32.0	27.2	24.8	16.8
MAGNESIUM, mg/l	1.70	1.46	1.46	2.19	13.12	8.74	6.32	8.74

TREATMENT OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

WET WEATHER MONITORING RESULTS

SELBY STREET OUTFALL (cont'd)

15 November 1966

SAMPLE TIME	9 0750	10 0810	11 0830	12 0850	13 0910	14 0930	15 0950	16 1020
FLOW, cfs	65	65	158	90	70	65	58	70
COLIFORM MPN - Conf./Fecal, 10^4/ml								
CONDUCTIVITY, μmho/cm	195	180	160	155	255	315	370	360
ALKALINITY, mg/1 as $CaCO_3$	48	42	35	35	69	78	83	86
SUSPENDED SOLIDS, mg/1	83	80	82	177	138	81	101	95
VOLATILE SUSPENDED SOLIDS, mg/1	36	36	39	38	71	39	34	65
GREASE, mg/1	4.6	7.2	8.6	10.5	6.3	5.3	4.9	9.8
COD, mg/1	138	126	151	212	159	159	134	155
BOD, mg/1	28	27	37	40	51	58	62	70
FLOATABLE PARTICULATES, mg/1	-	19	17	16	21	17	-	14
SETTLEABLE SOLIDS @ 30 Min., ml/1	-	<0.3	<0.3	1.0	<0.3	<0.3	-	<0.3
TOTAL KJELDAHL NITROGEN, mg/1 -N	11.6	8.4	6.0	13.0	17.2	20.0	25.6	27.7
AMMONIA NITROGEN, mg/1 -N	6.3	5.6	3.2	6.7	11.2	15.4	19.6	18.6
TOTAL PHOSPHATE, mg/1 PO_4	1.36	1.01	0.58	0.94	1.23	2.08	2.47	1.94
SULFATE, mg/1	18	24	20	20	18	20	26	32
CHLORIDE, mg/1	15.8	13.2	15.0	14.0	19.2	22.2	28.2	27.4
SODIUM, mg/1	13.5	13.0	12.0	12.0	18.0	21.5	25.0	24.0
POTASSIUM, mg/1	3.5	3.1	2.8	2.8	4.3	4.8	5.7	5.8
CALCIUM, mg/1	11.6	10.0	9.2	9.2	13.2	13.2	16.0	16.0
MAGNESIUM, mg/1	1.94	1.94	1.21	1.70	1.23	2.43	1.94	2.19

TREATMENT OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

WET WEATHER MONITORING RESULTS
SELBY STREET OUTFALL (cont'd)
15 November 1966

SAMPLE TIME	17 1050	18 1120	19 1150	20 1220				
FLOW, cfs	170	185	225	290				
COLIFORM MPN - Conf./Fecal, 10^4/ml								
CONDUCTIVITY, µmho/cm	265	165	275	235				
ALKALINITY, mg/l as $CaCO_3$	55	36	76	54				
SUSPENDED SOLIDS, mg/l	108	76	49	98				
VOLATILE SUSPENDED SOLIDS, mg/l	40	56	28	36				
GREASE, mg/l	6.1	6.6	17.7	11.3				
COD, mg/l	126	134	285	147				
BOD, mg/l	52	35	108	81				
FLOATABLE PARTICULATES, mg/l	-	5	-	15				
SETTLEABLE SOLIDS @ 30 Min., ml/l	-	<0.3	-	<0.3				
TOTAL KJELDAHL NITROGEN, mg/l -N	19.0	8.5	12.7	10.6				
AMMONIA NITROGEN, mg/l -N	11.6	3.9	5.3	4.2				
TOTAL PHOSPHATE, mg/l PO_4	2.04	1.26	4.80	3.22				
SULFATE, mg/l	28	24	32	26				
CHLORIDE, mg/l	11.4	16.2	23.8	19.0				
SODIUM, mg/l	17.0	13.5	28.0	23.0				
POTASSIUM, mg/l	4.6	3.1	4.9	4.4				
CALCIUM, mg/l	13.6	9.6	14.8	-				
MAGNESIUM, mg/l	1.46	1.46	3.40	-				

TREATMENT OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

WET WEATHER MONITORING RESULTS
SELBY STREET OUTFALL
14-15 November 1966

SAMPLE TIME	1 2155	2 2205	3 2215	4 2225	5 2235	6 2245	7 2305	8 2325
FLOW, cfs	167	150	125	90	80	70	55	55
COLIFORM MPN - Conf./Fecal, 10^4/ml								
CONDUCTIVITY, μmho/cm	360	166	144	148	140	136	134	130
ALKALINITY, mg/l as $CaCO_3$	59	37	28	30	30	27	25	25
SUSPENDED SOLIDS, mg/l	464	130	184	68	108	52	82	46
VOLATILE SUSPENDED SOLIDS, mg/l	272	62	78	38	48	20	34	32
GREASE, mg/l	42.1	28.1	24.7	14.2	15.5	8.9	10.1	11.7
COD, mg/l	560	428	272	223	165	165	140	132
BOD, mg/l	215	110	62	53	37	34	31	32
FLOATABLE PARTICULATES, mg/l	19	19	38	20	39	18	21	-
SETTLEABLE SOLIDS @ 30 Min., ml/l	7.7	2.0	0.8	<0.3	<0.3	<0.3	<0.3	-
TOTAL KJELDAHL NITROGEN, mg/l -N	17.6	11.6	8.8	6.7	6.0	6.4	5.6	4.2
AMMONIA NITROGEN, mg/l -N	2.5	2.8	2.8	1.8	1.4	1.1	0.7	0.7
TOTAL PHOSPHATE, mg/l PO_4	2.45	1.60	1.32	1.00	1.13	1.17	0.96	0.88
SULFATE, mg/l	34	22	24	26	20	20	28	20
CHLORIDE, mg/l	53.0	18.0	13.0	12.0	12.0	11.0	10.0	12.0
SODIUM, mg/l	38	15	12.5	12.5	12.0	11.8	12.0	11.5
POTASSIUM, mg/l	4.8	2.8	2.3	2.3	2.3	2.2	2.1	2.1
CALCIUM, mg/l	16.0	10.4	9.2	10.0	9.2	8.8	8.8	8.4
MAGNESIUM, mg/l	2.43	2.43	1.94	1.21	1.21	1.70	1.46	1.21

TREATMENT OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

WET WEATHER MONITORING RESULTS
SELBY STREET OUTFALL (cont'd)
14-15 November 1966

SAMPLE TIME	9 2345	10 0005	11 0035	12 0105				
FLOW, cfs	70	90	65	25				
COLIFORM MPN - Conf./Fecal, 10^4/ml								
CONDUCTIVITY, µmho/cm	122	116	116	116				
ALKALINITY, mg/l as $CaCO_3$	24	23	23	24				
SUSPENDED SOLIDS, mg/l	54	66	24	32				
VOLATILE SUSPENDED SOLIDS, mg/l	30	26	14	22				
GREASE, mg/l	3.5	4.8	5.2	5.7				
COD, mg/l	132	107	99	91				
BOD, mg/l	29	22	19	17				
FLOATABLE PARTICULATES, mg/l	27	-	25	-				
SETTLEABLE SOLIDS @ 30 Min., ml/l	<0.3	-	<0.3	-				
TOTAL KJELDAHL NITROGEN, mg/l -N	5.0	3.9	3.9	4.2				
AMMONIA NITROGEN, mg/l -N	0.4	0.4	0.7	0.7				
TOTAL PHOSPHATE, mg/l PO_4	0.80	0.78	0.76	0.76				
SULFATE, mg/l	26	26	20	22				
CHLORIDE, mg/l	12.2	11.2	10.6	11.2				
SODIUM, mg/l	11.0	10.5	10.0	10.0				
POTASSIUM, mg/l	2.0	1.9	2.0	1.9				
CALCIUM, mg/l	7.6	8.4	8.4	9.2				
MAGNESIUM, mg/l	1.21	0.97	1.21	0.97				

TREATMENT OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

WET WEATHER MONITORING RESULTS
SELBY STREET OUTFALL
20-21 January 1967

SAMPLE TIME	1 0710	2 0720	3 0730	4 0745	5 0800	6 0820	7 0840	8 0900
FLOW, cfs	210	210	200	190	190	170	210	227
COLIFORM MPN - Conf./Fecal, 10^4/ml								
CONDUCTIVITY, µmho/cm								
ALKALINITY, mg/l as $CaCO_3$	112	855	61	45	38.5	44	38.5	33.2
SUSPENDED SOLIDS, mg/l	696	1014	794	484	276	576	348	162
VOLATILE SUSPENDED SOLIDS, mg/l	386	470	360	224	128	324	184	68
GREASE, mg/l	52.2	69.4	49.9	39.4	22.2	46.4	31.0	17.2
COD, mg/l	676	952	732	436	252	560	404	188
BOD, mg/l	321	453	156	114	72	257	101	40
FLOATABLE PARTICULATES, mg/l	44.6	4.2	3.7	2.0	3.8	1.8	2.4	1.4
SETTLEABLE SOLIDS @ 30 Min., ml/l	32	41	31	8	12	42	21	11
TOTAL KJELDAHL NITROGEN, mg/l -N	26.95	21.70	15.05	7.00	6.65	13.65	7.35	3.50
AMMONIA NITROGEN, mg/l -N	7.70	4.55	3.50	1.75	1.05	2.45	0.70	0.35
TOTAL PHOSPHATE, mg/l PO_4	1.15	1.23	0.85	0.70	0.55	1.00	0.70	0.92
SULFATE, mg/l	92	72	50	32	33	22	16	15
CHLORIDE, mg/l	60.0	25.0	14.5	11.5	9.5	10.5	8.5	9.5
SODIUM, mg/l	40.0	16.2	11.0	9.2	7.2	8.0	8.0	8.0
POTASSIUM, mg/l	7.2	5.0	3.4	2.9	2.4	2.7	2.2	2.3
CALCIUM, mg/l	33.6	28.8	22.4	16.0	12.8	10.8	9.2	9.2
MAGNESIUM, mg/l	12.6	8.3	5.8	3.9	3.9	3.6	3.6	3.9
SETTLEABLE SOLIDS @ 30 min, mg/l	771	570	679	331	168	458	209	103
VOLATILE SETTLEABLE SOLIDS, mg/l	442	242	271	118	39	258	113	44
SETTLED COD, mg/l	241	237	155	94	-	-	118	61

TREATMENT OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

WET WEATHER MONITORING RESULTS
SELBY STREET OUTFALL (cont'd)
20-21 January 1967

SAMPLE TIME	9 0930	10 1000	11 1100	12 1200	13 1300	14 1500	15 1700	16 1800
FLOW, cfs	207	220	143	157	55	72	287	395
COLIFORM MPN - Conf./Fecal, 10^4/ml								
CONDUCTIVITY, µmho/cm								
ALKALINITY, mg/l as $CaCO_3$	30	24.6	28.9	32.1	34.2	44.0	23.6	25.7
SUSPENDED SOLIDS, mg/l	146	134	106	100	126	118	220	244
VOLATILE SUSPENDED SOLIDS, mg/l	54	56	36	40	54	48	54	64
GREASE, mg/l	10.5	9.6	11.0	8.6	10.1	13.9	9.8	15.0
COD, mg/l	140	164	132	112	308	200	196	160
BOD, mg/l	28	26	20	25	36.5	50	23	23
FLOATABLE PARTICULATES, mg/l	1.0	1.5	0.5	0.8	1.5	0.7	2.8	2.7
SETTLEABLE SOLIDS @ 30 Min., ml/l	2	2	2	2	2	2	5	2
TOTAL KJELDAHL NITROGEN, mg/l -N	0.70	1.40	1.05	0.70	1.05	1.75	-	2.45
AMMONIA NITROGEN, mg/l -N	-	-	-		-	-	-	-
TOTAL PHOSPHATE, mg/l PO_4	0.55	0.66	0.68	0.80	0.86	1.18	0.48	0.44
SULFATE, mg/l	-	15	-	13	-	24	14	12
CHLORIDE, mg/l	7.5	6.3	6.7	8.5	48.0	49.2	32.0	4.2
SODIUM, mg/l	7.2	6.5	8.5	9.0	29.0	31.0	6.0	5.5
POTASSIUM, mg/l	2.1	1.7	1.8	2.1	3.1	3.6	1.1	1.4
CALCIUM, mg/l	8.0	7.6	7.6	8.0	9.6	13.6	6.4	7.6
MAGNESIUM, mg/l	2.7	2.2	2.2	1.7	4.1	2.9	1.5	1.2
SETTLEABLE SOLIDS @ 30 min, mg/l	104	119	88	54	51	72	247	211
VOLATILE SETTLEABLE SOLIDS, mg/l	31	43	31	19	25	26	74	59
SETTLED COD, mg/l	40.8	44.9	40.8	40.8	77.5	102	65.2	44.9

TREATMENT OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

WET WEATHER MONITORING RESULTS

SELBY STREET OUTFALL (cont'd)

20-21 January 1967

SAMPLE TIME	17 1900	18 2100	19 2300	20 0100	21 0300	22 0425	23 0500	24 0745
FLOW, cfs	237	173	380	163	46	395	315	430
COLIFORM MPN - Conf./Fecal, 10^4/ml								
CONDUCTIVITY, umho/cm								
ALKALINITY, mg/l as $CaCO_3$	23.6	19.3	30	22.5	25.7	27.8	19.3	20.3
SUSPENDED SOLIDS, mg/l	174	120	106	134	76	90	132	132
VOLATILE SUSPENDED SOLIDS, mg/l	46	34	32	40	22	25	26	29
GREASE, mg/l	8.2	9.1	5.6	3.2	1.2	6.2	17.8	4.7
COD, mg/l	140	82	96	40	84	140	100	52
BOD, mg/l	16	16	22	4.2	26.5	21.5	29.2	11.0
FLOATABLE PARTICULATES, mg/l	5.2	8.9	0.8	1.8	0.6	2.3	4.5	6.4
SETTLEABLE SOLIDS @ 30 Min., ml/l	2	2	2	2	2	2	2	2
TOTAL KJELDAHL NITROGEN, mg/l -N	0.70	0.70	1.05	0.70	0.35	1.75	1.05	-
AMMONIA NITROGEN, mg/l -N	-	-	-	-	-	0.35	-	-
TOTAL PHOSPHATE, mg/l PO_4	0.50	1.39	0.40	0.40	0.25	0.30	0.22	0.24
SULFATE, mg/l	16	16	16	17	17	13	28	24
CHLORIDE, mg/l	4.7	5.5	7.0	5.0	7.0	5.5	15.0	5.0
SODIUM, mg/l	6.0	6.5	7.5	5.5	7.2	6.0	6.0	5.0
POTASSIUM, mg/l	1.5	1.4	1.5	1.4	1.4	1.2	1.3	1.2
CALCIUM, mg/l	6.8	6.4	8.4	6.0	8.8	8.0	6.4	6.0
MAGNESIUM, mg/l	1.5	1.5	1.9	1.5	2.2	2.2	2.7	1.7
SETTLEABLE SOLIDS @ 30 min, mg/l	103	158	142	67	29	208	177	134
VOLATILE SETTLEABLE SOLIDS, mg/l	26	33	33	12	5	56	50	28
SETTLED COD, mg/l	61.2	44.9	44.9	28.5	40.8	20.4	36.7	16.3

TREATMENT OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

WET WEATHER MONITORING RESULTS
SELBY STREET OUTFALL (cont'd)
20-21 January 1967

SAMPLE TIME	25 0925	26 1130	27 1330	28 1529	29 1730	30 1930	31 2130	32 2330
FLOW, cfs	390	395	390	143	240	390	170	65
COLIFORM MPN - Coif./Fecal, 10^4/ml								
CONDUCTIVITY, μmho/cm								
ALKALINITY, mg/l as $CaCO_3$	27.8	23.6	22.5	40.7	67.5	24.6	31	62
SUSPENDED SOLIDS, mg/l	194	193	232	149	157	173	100	107
VOLATILE SUSPENDED SOLIDS, mg/l	34	53	37	28	47	30	22	19
GREASE, mg/l	2.1	2.5	3.7	2.9	1.9	2.3	1.4	0.9
COD, mg/l	92	80	76	76	124	72	60	68
BOD, mg/l	15.8	13.0	11.0	13.3	28.3	14.4	11.0	11.0
FLOATABLE PARTICULATES, mg/l	5.0	5.1	4.6	1.8	2.1	7.9	6.7	5.1
SETTLEABLE SOLIDS @ 30 Min., ml/l	2	2	2	2	2	2	2	1
TOTAL KJELDAHL NITROGEN, mg/l -N	2.10		0.70		3.50		0.35	5.25
AMMONIA NITROGEN, mg/l -N								
TOTAL PHOSPHATE, mg/l PO_4	0.40	0.32	0.47	0.78	1.62	0.40	0.38	0.71
SULFATE, mg/l	26	24	26	24	46	16	14	40
CHLORIDE, mg/l	6.2	8.7	6.7	4.5	29.5	8.9	13.0	26.5
SODIUM, mg/l	8.0	7.5	7.0	14.5	26.5	8.5	11.0	21.0
POTASSIUM, mg/l	1.9	1.5	1.5	2.7	4.5	1.9	2.2	3.8
CALCIUM, mg/l	9.6	7.2	6.8	16.4	30.4	8.8	12.8	26.4
MAGNESIUM, mg/l	2.9	2.4	2.9	3.4	5.3	2.9	2.9	4.9
SETTLEABLE SOLIDS @ 30 min, mg/l	144	185	191	93	83	84	58	36
VOLATILE SETTLEABLE SOLIDS, mg/l	23	28	29	17	25	14	11	8
SETTLED COD, mg/l	32.6	32.6						

TREATMENT OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

WET WEATHER MONITORING RESULTS
SELBY STREET OUTFALL (cont'd)
20-21 January 1967

SAMPLE TIME	33 0130							
FLOW, cfs	55							
COLIFORM MPN - Conf./Fecal, 10^4/ml								
CONDUCTIVITY, µmho/cm								
ALKALINITY, mg/l as $CaCO_3$	81							
SUSPENDED SOLIDS, mg/l	97							
VOLATILE SUSPENDED SOLIDS, mg/l	21							
GREASE, mg/l	0.9							
COD, mg/l	84							
BOD, mg/l	13.3							
FLOATABLE PARTICULATES, mg/l	3.2							
SETTLEABLE SOLIDS @ 30 Min., ml/l	1							
TOTAL KJELDAHL NITROGEN, mg/l -N								
AMMONIA NITROGEN, mg/l -N								
TOTAL PHOSPHATE, mg/l PO_4	1.02							
SULFATE, mg/l	60							
CHLORIDE, mg/l	38.5							
SODIUM, mg/l	30.5							
POTASSIUM, mg/l	5.3							
CALCIUM, mg/l	33.6							
MAGNESIUM, mg/l	10.2							
SETTLEABLE SOLIDS @ 30 min, mg/l	40							
VOLATILE SETTLEABLE SOLIDS, mg/l	9							

TREATMENT OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

WET WEATHER MONITORING RESULTS
SELBY STREET OUTFALL

23-24 January 1967

SAMPLE TIME	1 2125	2 2140	3 2210	4 2230	5 2300	6 2330	7 0040	8 0135
FLOW, cfs	70	70	130	200	290	300	385	440
COLIFORM MPN - Conf./Fecal, 10^4/ml	23/<2.3	6/6	13/5	70/2.3	>240/0.6	24/1.3	5/<0.23	0.23/0.06
CONDUCTIVITY, umho/cm								
ALKALINITY, mg/l as $CaCO_3$	196	198	187	98.5	49.2	25.7	21.4	18.2
SUSPENDED SOLIDS, mg/l	122	80	124	515	418	149	133	131
VOLATILE SUSPENDED SOLIDS, mg/l	74	53	93	343	271	43	31	21
GREASE, mg/l	10.5	18.7	16.2	68.2	25.7	11.9	2.3	3.2
COD, mg/l	199	245	314	655	269	94	61	41
BOD, mg/l	137	125	174	220	91	28	11	3.5
FLOATABLE PARTICULATES, mg/l	1.9	5.0	1.3	0.9	3.8	3.1	2.6	1.7
SETTLEABLE SOLIDS @ 30 Min., ml/l	1	1	1	85	60	13	8	2
TOTAL KJELDAHL NITROGEN, mg/l -N	14.70	16.45	15.75	14.00	6.30	2.45	1.05	0.35
AMMONIA NITROGEN, mg/l -N								
TOTAL PHOSPHATE, mg/l PO_4	7.50	4.85	4.50	1.21	1.02	0.61	0.57	0.45
SULFATE, mg/l	72	62	54	34	14	Nil	Nil	Nil
CHLORIDE, mg/l	129.2	97.5	97.5	47.5	21.5	11.2	7.0	7.5
SODIUM, mg/l	84.5	72.0	65.0	14.0	7.0	6.0	6.0	6.0
POTASSIUM, mg/l	9.9	9.5	11.2	5.4	2.4	1.1	1.0	0.8
CALCIUM, mg/l	46.4	42.4	40.0	20.0	13.6	6.4	6.0	5.6
MAGNESIUM, mg/l	13.1	11.2	12.2	9.7	2.4	1.9	1.7	1.0
SETTLEABLE SOLIDS @ 30 min., mg/l	72	27	53	450	300	159	110	147
VOLATILE SETTLEABLE SOLIDS, mg/l	21	5	28	310	170	55	39	21
SETTLED COD, mg/l	159	241	306	2209	98	49	65	32.6

TREATMENT OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

WET WEATHER MONITORING RESULTS
SELBY STREET OUTFALL (Cont'd)
23-24 January 1967

SAMPLE TIME	9 0330							
FLOW, cfs	195							
COLIFORM MPN - Conf./Fecal, 10^4/ml	1.3/0.06							
CONDUCTIVITY, µmho/cm								
ALKALINITY, mg/l as $CaCO_3$	17.1							
SUSPENDED SOLIDS, mg/l	287							
VOLATILE SUSPENDED SOLIDS, mg/l	46							
GREASE, mg/l	4.9							
COD, mg/l	74							
BOD, mg/l	6.2							
FLOATABLE PARTICULATES, mg/l	2.9							
SETTLEABLE SOLIDS @ 30 Min., ml/l	1							
TOTAL KJELDAHL NITROGEN, mg/l -N	1.40							
AMMONIA NITROGEN, mg/l -N								
TOTAL PHOSPHATE, mg/l PO_4	0.50							
SULFATE, mg/l	Nil							
CHLORIDE, mg/l	11.2							
SODIUM, mg/l	5.0							
POTASSIUM, mg/l	1.0							
CALCIUM, mg/l	4.0							
MAGNESIUM, mg/l	1.5							
SETTLEABLE SOLIDS, @ 30 min., mg/l	125							
VOLATILE, SETTLEABLE SOLIDS, mg/l	23							
SETTLED COD, mg/l	49							

TREATMENT OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

WET WEATHER MONITORING RESULTS
SELBY STREET OUTFALL
24 February 1967

SAMPLE TIME	1 2050	2 2100	3 2110	4 2120	5 2140	6 2200		
FLOW, cfs	245	185	115	72	40	15		
COLIFORM MPN - Conf./Fecal, 10^4/ml	37/6	130/6	62/62	23/<2.3	6/6	6/6		
CONDUCTIVITY, µmho/cm								
ALKALINITY, mg/l as $CaCO_3$	219.3	107	40.7	30	27.8	23.5		
SUSPENDED SOLIDS, mg/l	1236	1260	552	260	167	109		
VOLATILE SUSPENDED SOLIDS, mg/l	886	702	282	128	87	52		
GREASE, mg/l	1.2	120.5	20.3	34.6	5.1	12.9		
COD, mg/l	1762	1275	603	323	205	157		
BOD, mg/l	480	458	167	88.5	56.5	50		
FLOATABLE PARTICULATES, mg/l	17.9	7.8	2.9	3.8				
SETTLEABLE SOLIDS @ 30 Min., ml/l	145	85	20	13				
TOTAL KJELDAHL NITROGEN, mg/l -N	54.0	34.3	12.95	7.7	5.6	3.85		
AMMONIA NITROGEN, mg/l -N	16.8	4.9	1.05	1.4	0.7	0.35		
TOTAL PHOSPHATE, mg/l PO_4	8.55	2.75	0.58	0.46	0.73	0.34		
SULFATE, mg/l	28	75	14	11	10	80		
CHLORIDE, mg/l	96	26	19	17	16	16		
SODIUM, mg/l	76.5	25.0	13.0	11.8	10.5	10.5		
POTASSIUM, mg/l	12.3	5.4	2.6	2.4	2.1	2.0		
CALCIUM, mg/l	23.2	22.4	15.2	13.6	12.8	11.2		
MAGNESIUM, mg/l	19.9	5.8	2.9	5.1	3.1	2.9		
SETTLEABLE SOLIDS, mg/l	1067	959	498	164				

TREATMENT OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

WET WEATHER MONITORING RESULTS
SELBY STREET OUTFALL
10 March 1967

SAMPLE TIME	1 2150	2 2200	3 2210	4 2220	5 2230	6 2240	7 2300	8 2320
FLOW, cfs	150	165	185	190	165	160	185	180
COLIFORM MPN - Conf./Fecal, 10^4/ml	23/23	62/13	62/6	62/<2.3	>240/5	24/0.6	24/<0.23	2.3/<0.23
CONDUCTIVITY, umho/cm	480	366	343	256	206	163	164.5	153.5
ALKALINITY, mg/l as $CaCO_3$	109	91.1	73.3	59.4	45.4	37.6	35.6	35.6
SUSPENDED SOLIDS, mg/l	294	386	450	548	450	454	272	446
VOLATILE SUSPENDED SOLIDS, mg/l	174	198	224	266	206	278	123	176
GREASE, mg/l	69.3	63.8	93.0	83.6	62.5	34.5	39.7	27.2
COD, mg/l	443	541	472	528	432	183	242	202
BOD, mg/l	172	225	194	201	153	74	87	73
FLOATABLE PARTICULATES, mg/l	2.4	7.9	3.4	3.9	6.5	3.0	2.7	1.3
SETTLEABLE SOLIDS @ 30 Min., ml/l	14	12	28	32	25	11	15	5
TOTAL KJELDAHL NITROGEN, mg/l -N	18.55	19.60	17.85	15.05	13.50	14.70	6.65	5.60
AMMONIA NITROGEN, mg/l -N	7.70	7.00	4.90	3.50	2.80	2.45	1.40	1.40
TOTAL PHOSPHATE, mg/l PO_4	.94	1.30	1.24	.99	.61	.56	.72	.54
SULFATE, mg/l	34	27	21	16	14	15	28	15
CHLORIDE, mg/l	67	43	37	27	21	16	9	11.5
SODIUM, mg/l	48.0	32.0	26.0	17.8	15.5	12.5	11.0	10.2
POTASSIUM, mg/l	6.90	5.10	4.15	3.10	2.55	2.00	2.10	1.85
CALCIUM, mg/l	20.0	18.4	16.8	14.4	12.0	9.6	8.8	9.6
MAGNESIUM, mg/l	10.2	8.7	8.3	4.9	4.4	3.9	2.4	3.9

TREATMENT OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

WET WEATHER MONITORING RESULTS
SELBY STREET OUTFALL (cont'd)
10 March 1967

SAMPLE TIME	9 2340	10 0010	11 0040					
FLOW, cfs	720	620	330					
COLIFORM MPN - Conf./Fecal, 10^4/ml	1.3/0.23	>24/0.62	7/0.12					
CONDUCTIVITY, umho/cm	131.5	74.8	109.5					
ALKALINITY, mg/l as $CaCO_3$	41.5	19.8	23.8					
SUSPENDED SOLIDS, mg/l	874	920	370					
VOLATILE SUSPENDED SOLIDS, mg/l	388	212	94					
GREASE, mg/l	72.7	29.7	15.5					
COD, mg/l	395	185	137					
BOD, mg/l	88	56	30					
FLOATABLE PARTICULATES, mg/l	4.1	9.3	4.8					
SETTLEABLE SOLIDS @ 30 Min., ml/l	25	8	2					
TOTAL KJELDAHL NITROGEN, mg/l -N	3.50	5.25	2.45					
AMMONIA NITROGEN, mg/l -N	1.05	1.75	1.05					
TOTAL PHOSPHATE, mg/l PO_4	.58	.23	.66					
SULFATE, mg/l	13	13	14					
CHLORIDE, mg/l	12	5.5	9					
SODIUM, mg/l	9.5	5.5	8.0					
POTASSIUM, mg/l	1.55	1.10	1.50					
CALCIUM, mg/l	9.2	7.2	7.2					
MAGNESIUM, mg/l	5.1	2.9	2.4					

TREATMENT OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

WET WEATHER MONITORING RESULTS

SELBY STREET OUTFALL

15 March 1967

SAMPLE TIME	1 2225	2 2235	3 2250	4 2305	5 2324	6 2339	7 0010	8 0105
FLOW, cfs	125	257	407	310	480	530	240	180
COLIFORM MPN - Conf./Fecal, 10^4/ml	2.3/2.3	24/6.2	5/<0.23	6.2/<0.23	6.2/<0.23	2.3/2.3	6.2/0.6	2.3/<0.23
CONDUCTIVITY, umho/cm	714	505	283	119	82.2	91.4	109.5	68.5
ALKALINITY, mg/1 as $CaCO_3$	182	158	77	33.6	13.8	21.7	18.7	18.1
SUSPENDED SOLIDS, mg/1	378	564	576	302	320	231	222	174
VOLATILE SUSPENDED SOLIDS, mg/1	178	386	312	122	90	66	45	32
GREASE, mg/1	67.7	122.0	46.7	25.2	8.7	9.2	3.9	3.7
COD, mg/1	439	753	360	178	132	62	54	33
BOD, mg/1	216	345	124	55	23	17	5	2
FLOATABLE PARTICULATES, mg/1								
SETTLEABLE SOLIDS @ 30 Min., ml/1								
TOTAL KJELDAHL NITROGEN, mg/1 -N	16.45	22.75	11.55	2.45	1.05	1.75	2.10	Nil
AMMONIA NITROGEN, mg/1 -N	11.9	8.4	4.2	Nil	Nil	Nil	Nil	Nil
TOTAL PHOSPHATE, mg/1 PO_4	3.26	3.26	2.41	0.65	1.87	0.72	0.32	0.39
SULFATE, mg/1	38	31	22	--	14	13	14	13
CHLORIDE, mg/1	86	28	23	9	5	5	5.5	4.5
SODIUM, mg/1	71.0	46.0	20.8	8.2	6.0	5.5	6.0	5.5
POTASSIUM, mg/1	11.0	7.55	3.65	1.55	1.25	1.20	1.45	1.35
CALCIUM, mg/1	32.0	17.6	13.6	6.4	4.8	4.8	4.4	5.2
MAGNESIUM, mg/1	9.2	11.0	6.8	4.4	2.9	1.5	1.2	2.7

TREATMENT OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

WET WEATHER MONITORING RESULTS

SELBY STREET OUTFALL (cont'd)

15 March 1967

SAMPLE TIME	9 0134							
FLOW, cfs	140							
COLIFORM MPN - Conf./Fecal, 10^4/ml	2.3/<0.23							
CONDUCTIVITY, umho/cm	122.5							
ALKALINITY, mg/l as $CaCO_3$	22.7							
SUSPENDED SOLIDS, mg/l	127							
VOLATILE SUSPENDED SOLIDS, mg/l	27							
GREASE, mg/l	2.3							
COD, mg/l	33							
BOD, mg/l	2							
FLOATABLE PARTICULATES, mg/l								
SETTLEABLE SOLIDS @ 30 Min., ml/l								
TOTAL KJELDAHL NITROGEN, mg/l -N	2.10							
AMMONIA NITROGEN, mg/l -N	.35							
TOTAL PHOSPHATE, mg/l PO_4	0.45							
SULFATE, mg/l	15							
CHLORIDE, mg/l	7							
SODIUM, mg/l	7.5							
POTASSIUM, mg/l	1.55							
CALCIUM, mg/l	8.0							
MAGNESIUM, mg/l	1.5							

TREATMENT OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

WET WEATHER MONITORING RESULTS
LAGUNA STREET OUTFALL
10 March 1967

SAMPLE TIME	1 2045	2 2055	3 2105	4 2115	5 2125	6 2135	7 2155	8 2215
FLOW, cfs	7.35	7.35	7.35	7.35	7.35	14.35	18.9	7.35
COLIFORM MPN - Conf./Fecal, 10^4/ml	4.6/4.6	6/<2.3	23/<2.3	<2.3/<2.3	<2.3/<2.3	23/<2.3	6.2/0.6	24/0.6
CONDUCTIVITY, umho/cm	310.8	297.0	274.0	260.0	206.0	187.5	146.3	146.3
ALKALINITY, mg/l as $CaCO_3$	73.3	59.4	53.5	49.5	43.5	39.6	35.6	33.7
SUSPENDED SOLIDS, mg/l	165	190	129	116	203	203	378	166
VOLATILE SUSPENDED SOLIDS, mg/l	111	129	86	80	123	118	206	107
GREASE, mg/l	35.6	38.2	23.3	23.6	47.3	28.0	34.5	14.2
COD, mg/l	208	256	172	136	192	136	232	108
BOD, mg/l	146	132	97	81	88	65	88	46
FLOATABLE PARTICULATES, mg/l	1.0	1.4	1.2	1.6	4.4	2.4	3.6	2.1
SETTLEABLE SOLIDS @ 30 Min., ml/l	15	16	10	7	11	10	15	8
TOTAL KJELDAHL NITROGEN, mg/l -N	13.65	14.00	11.55	11.90	8.05		7.35	5.25
AMMONIA NITROGEN, mg/l -N	4.20	4.20	3.85	2.80	3.50	23.80	3.15	2.10
TOTAL PHOSPHATE, mg/l PO_4	1.30	1.92	1.42	1.62	0.81	0.81	0.70	0.68
SULFATE, mg/l	26	25	23	21	17	16	13	14
CHLORIDE, mg/l	31	29	26.5	23.5	15.5	14	11	10
SODIUM, mg/l	26.0	23.8	20.0	19.5	13.5	12.5	9.5	10.0
POTASSIUM, mg/l	5.15	4.75	4.20	3.75	3.25	2.75	2.25	2.25
CALCIUM, mg/l	15.2	13.6	12.8	11.2	11.2	10.4	8.8	7.2
MAGNESIUM, mg/l	4.9	5.3	5.8	4.9	3.9	4.9	2.9	2.4

TREATMENT OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

WET WEATHER MONITORING RESULTS
LAGUNA STREET OUTFALL (Cont'd)
10 March 1967

SAMPLE TIME	9 2235	10 2300	11 2330	12 2400				
FLOW, cfs	7.35	11.6	80.6	28.6				
COLIFORM MPN - Conf./Fecal, 10^4/ml	6.2/<0.23	2.3/2.3	6.2/2.3	0.6/0.6				
CONDUCTIVITY, μmho/cm	200.5	118.0	111.5	64.0				
ALKALINITY, mg/l as $CaCO_3$	49.5	29.7	23.8	21.8				
SUSPENDED SOLIDS, mg/l	104	117	483	83				
VOLATILE SUSPENDED SOLIDS, mg/l	74	57	188	36				
GREASE, mg/l	--	11.8	31.4	24.6				
COD, mg/l	120	88	236	48				
BOD, mg/l	89.5	38	56	11				
FLOATABLE PARTICULATES, mg/l	2.8	1.9	7.8	3.2				
SETTLEABLE SOLIDS @ 30 Min., ml/l	5	6	7	2				
TOTAL KJELDAHL NITROGEN, mg/l -N	7.35	4.55	4.55	Nil				
AMMONIA NITROGEN, mg/l -N	2.10	1.40	1.05	Nil				
TOTAL PHOSPHATE, mg/l PO_4	1.38	0.52	0.66	0.24				
SULFATE, mg/l	17		11	10				
CHLORIDE, mg/l	15.5	8.0	6.5	5.0				
SODIUM, mg/l	15.8	8.5	7.0	5.0				
POTASSIUM, mg/l	3.45	1.90	1.40	1.05				
CALCIUM, mg/l	7.2	6.4	6.8	4.0				
MAGNESIUM, mg/l	3.9	3.4	1.5	0.97				

TREATMENT OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

WET WEATHER MONITORING RESULTS

LAGUNA STREET OUTFALL

15 March 1967

SAMPLE TIME	1 2020	2 2030	3 2045	4 2100	5 2115	6 2130	7 2215	8 2230
FLOW, cfs	7.0	12.5	11.4	7.2	4.8	2.0	44	108
COLIFORM MPN - Conf./Fecal, 10^4/ml	70/13	70/2.3	24/6.2	2.3/2.3	6.2/6.2	6.2/0.46	5/2.3	70/0.6
CONDUCTIVITY, umho/cm	338	220	200.8	178	206	219.8	158.3	76.8
ALKALINITY, mg/l as $CaCO_3$	82	43.4	27.6	35.5	46.4	51.3	29.6	16.8
SUSPENDED SOLIDS, mg/l	304	442	194	130	104	73	187	237
VOLATILE SUSPENDED SOLIDS, mg/l	234	264	149	86	81	56	92	119
GREASE, mg/l	63.4	18.7	28.4	16.2	18.5	18.3	20.5	17.9
COD, mg/l	458	425	210	198	169	251	210	165
BOD, mg/l	252	169	97	104	92	108	51	41
FLOATABLE PARTICULATES, mg/l	2.3	1.5	1.1	1.0	2.2	0.4	0.8	1.1
SETTLEABLE SOLIDS @ 30 Min., ml/l	40	35	13	7	12	10	5	15
TOTAL KJELDAHL NITROGEN, mg/l -N	19.95	15.75	13.30	8.05	8.75	10.85	7.00	3.85
AMMONIA NITROGEN, mg/l -N	10.50	4.20	2.80	3.50	4.20	4.55	1.40	2.45
TOTAL PHOSPHATE, mg/l PO_4	3.20	2.12	1.47	1.41	1.86	1.40	1.17	1.13
SULFATE, mg/l	29	18	15	18	17	19	17	10
CHLORIDE, mg/l	32	21	21	14	19.5	18	14	5.5
SODIUM, mg/l	29.5	18.5	19.0	14.5	18.0	16.0	11.0	6.0
POTASSIUM, mg/l	6.70	3.65	2.90	3.00	3.35	3.85	2.75	1.15
CALCIUM, mg/l	11.2	10.4	8.0	8.4	8.0	8.8	7.2	4.8
MAGNESIUM, mg/l	4.9	2.9	1.9	3.2	3.2	3.2	3.4	2.4

TREATMENT OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

WET WEATHER MONITORING RESULTS
LAGUNA STREET OUTFALL (cont'd)
15 March 1967

SAMPLE TIME	9 2245	10 2300	11 2315	12 2340	13 2400			
FLOW, cfs	48	11.4	76.0	65.7	44			
COLIFORM MPN - Conf./Fecal, 10^4/ml	6.2/0.6	2.3/<0.23	2.3/2.3	0.6/<0.23	<0.23/<023			
CONDUCTIVITY, µmho/cm	62.3	91.5	109.0	84.1	71.4			
ALKALINITY, mg/l as $CaCO_3$	13.8	20.8	24.7	15.8	14.8			
SUSPENDED SOLIDS, mg/l	95	75	60	67	53			
VOLATILE SUSPENDED SOLIDS, mg/l	48	32	34	28	29			
GREASE, mg/l	7.2	5.2	6.7	2.2	6.7			
COD, mg/l	78	58	58	45	41			
BOD, mg/l	14	51	29	26	4			
FLOATABLE PARTICULATES, mg/l	No sample	2.6	1.8	0.7	0.7			
SETTLEABLE SOLIDS @ 30 Min., ml/l	No sample	-	-	-	-			
TOTAL KJELDAHL NITROGEN, mg/l -N	3.85	3.15	2.80	1.05	1.05			
AMMONIA NITROGEN, mg/l -N	1.05	2.10	2.10	0.35	Nil			
TOTAL PHOSPHATE, mg/l PO_4	No sample				0.49			
SULFATE, mg/l	10	6	9	5	5			
CHLORIDE, mg/l	No sample		5.0	No sample	3.0			
SODIUM, mg/l	5.0	2.0	7.5	5.0	5.0			
POTASSIUM, mg/l	1.05	1.40	1.65	1.20	1.10			
CALCIUM, mg/l		4.0	5.6	4.4	4.0			
MAGNESIUM, mg/l		1.5	1.9	0.7	1.5			

APPENDIX E

SPECIFIC MASS DISCHARGE FACTORS

TABLE E-1

MASS DISCHARGE RELATIONSHIPS FOR
SELBY STREET OUTFALL

CONSTITUENT: BOD

Date of Storm	Rainfall (in)	Runoff Factor (percent)	Mass Discharge (10^3 lb) Total	Mass Discharge (10^3 lb) Due to Storm	Mass Discharge Factor, (lbs per Acre-Inch of Runoff) Total	Mass Discharge Factor, (lbs per Acre-Inch of Runoff) Due to Storm	
6 Nov. 66	0.98	35.8	18.50	14.58	15.4	12.2	
14 Nov. 66	0.42	59.6	3.00	1.54	15,2	9.85	
15 Nov. 66			9.90	6.82			
20 Jan. 67	3.92	81.3	56.80	23.80	5.25	2.20	
23 Jan. 67	0.72	84.6	14.40	12.33	6.95	5.95	
24 Feb. 67	0.22	13.7	6.94	5.95	67.7	57.9	
10 Mar. 67	1.34	31.0	18.00	16.34	12.8	11.6	10.84
15 Mar. 67	0.74	34.8	9.62	8.37	11.1	9.68	
Totals	8.34		137.16	89.73			
Flow-weighted Means		59.2			8.11	5.31	

TABLE E-1 (cont'd)

MASS DISCHARGE RELATIONSHIPS FOR SELBY STREET OUTFALL

CONSTITUENT: COD

Date of Storm	Rainfall (in)	Runoff Factor (percent)	Mass Discharge (10^3 lb)		Mass Discharge Factor (lbs per Acre-Inch of Runoff)		
			Total	Due to Storm	Total	Due to Storm	
6 Nov. 66	0.98	35.8	102.0	91.9	85.5	77.1	
14 Nov. 66	0.42	59.6	11.7	8.1	46.0	30.4	
15 Nov. 66			27.5	17.8			
20 Jan. 67	3.92	81.3	292.5	232.5	27.0	21.4	
23 Jan. 67	0.72	84.6	53.5	48.1	25.8	23.2	
24 Feb. 67	0.22	13.7	20.8	18.4	203.0	179.6	
10 Mar. 67	1.34	31.0	61.0	57.1	43.2	40.45	38.2
15 Mar. 67	0.74	34.8	32.4	29.4	37.0	33.6	
Totals	8.34		601.4	503.3			
Flow-weighted Means		59.2			35.8	29.8	

TABLE E-1 (cont'd)

MASS DISCHARGE RELATIONSHIPS FOR
SELBY STREET OUTFALL

CONSTITUENT: Suspended Solids

Date of Storm	Rainfall (in)	Runoff Factor (percent)	Mass Discharge (10^3 lb)		Mass Discharge Factor (lbs per Acre-Inch of Runoff)		
			Total	Due to Storm	Total	Due to Storm	
6 Nov. 66	0.98	35.8	204.0	199.4	171.0	167.2	
14 Nov. 66	0.42	59.6	11.9	10.0	30.4	22.6	
15 Nov. 66			13.7	9.2			
20 Jan. 67	3.92	81.3	429.0	402.9	39.6	37.2	
23 Jan. 67	0.72	84.6	99.5	96.9	48.0	46.7	
24 Feb. 67	0.22	13.7	17.9	16.8	175.0	164.2	
10 Mar. 67	1.34	31.0	155	153	110	109	93.0
15 Mar. 67	0.74	34.8	60.5	59.0	69.1	67.5	
Totals	8.34		852.0	807.7			
Flow-weighted Means		59.2			56.5	53.8	

TABLE E-1 (cont'd)

MASS DISCHARGE RELATIONSHIPS FOR
SELBY STREET OUTFALL

CONSTITUENT: Volatile Suspended Solids

Date of Storm	Rainfall (in)	Runoff Factor (percent)	Mass Discharge (10^3 lb) Total	Mass Discharge (10^3 lb) Due to Storm	Mass Discharge Factor (lbs per Acre-Inch of Runoff) Total	Mass Discharge Factor (lbs per Acre-Inch of Runoff) Due to Storm	
6 Nov. 66	0.98	35.8	39.70	35.94	35.0	29.9	
14 Nov. 66	0.42	59.6	2.90	1.54	11.09	5.78	
15 Nov. 66			6.52	3.38			
20 Jan. 67	3.92	81.3	126.40	107.40	11.66	9.91	
23 Jan. 67	0.72	84.6	33.10	31.12	16.00	15.0	
24 Feb. 67	0.22	13.7	11.00	10.20	107.60	100.0	
10 Mar. 67	1.34	31.0	51.00	49.66	36.1	35.2	31.2
15 Mar. 67	0.74	34.8	22.80	21.64	26.0	24.75	
Totals	8.34		293.42	260.88			
Flow-weighted Means		59.2			17.5	15.6	

TABLE E-1 (cont'd)

MASS DISCHARGE RELATIONSHIPS FOR
SELBY STREET OUTFALL

CONSTITUENT: Floatables

Date of Storm	Rainfall (in)	Runoff Factor (percent)	Mass Discharge (10^3 lb)		Mass Discharge Factor (lbs per Acre-Inch of Runoff)	
			Total	Due to Storm	Total	Due to Storm
6 Nov. 66	0.98	35.8	1.95	1.89	1.62	1.57
14 Nov. 66	0.42	59.6	0.14	0.12	0.40	0.294
15 Nov. 66			0.20	0.13		
20 Jan 67	3.92	81.3	10.60	10.17	0.977	0.938
23 Jan. 67	0.72	84.6	1.20	1.17	0.58	0.565
24 Feb. 67	0.22	13.7	0.19	0.18	1.86	1.76
10 Mar. 67	1.34	31.0	1.22	1.20	0.865	0.85
15 Mar. 67	0.74	34.8	-	-	-	-
Totals	8.34		15.50	14.86		
Flow-weighted Means		59.2			0.97	0.93

TABLE E-1 (cont'd)

MASS DISCHARGE RELATIONSHIPS FOR
SELBY STREET OUTFALL

CONSTITUENT: Grease

Date of Storm	Rainfall (in)	Runoff Factor (percent)	Mass Discharge (10^3 lb)		Mass Discharge Factor (lbs per Acre-Inch of Runoff)		
			Total	Due to Storm	Total	Due to Storm	
6 Nov. 66	0.98	35.8	9.30	8.88	7.74	7.39	
14 Nov. 66	0.42	59.6	0.75	0.36	2.52	1.20	
15 Nov. 66			1.39	0.66			
20 Jan. 67	3.92	81.3	17.50	14.07	1.615	1.298	
23 Jan. 67	0.72	84.6	4.65	4.08	2.245	1.972	
24 Feb. 67	0.22	13.7	1.11	0.80	10.86	7.83	
10 Mar. 67	1.34	31.0	10.25	9.81	7.26	6.95	5.96
15 Mar. 67	0.74	34.8	4.12	3.82	4.70	4.36	
Totals	8.34		49.07	42.48			
Flow-weighted Means		59.2			2.92	2.54	

TABLE E-1 (cont'd)

MASS DISCHARGE RELATIONSHIPS FOR SELBY STREET OUTFALL

CONSTITUENT: Total Nitrogen

Date of Storm	Rainfall (in)	Runoff Factor (percent)	Mass Discharge (10^3 lb) Total	Mass Discharge (10^3 lb) Due to Storm	Mass Discharge Factor (lbs per Acre-Inch of Runoff) Total	Mass Discharge Factor (lbs per Acre-Inch of Runoff) Due to Storm	
6 Nov. 66	0.98	35.8	2.75	2.02	2.285	1.68	
14 Nov. 66			0.34	0.11			
	0.42	59.6			2.930	1.61	
15 Nov. 66			2.15	1.26			
20 Jan. 67	3.92	81.3	4.95	0.89	0.456	0.082	
23 Jan. 67	0.72	84.6	1.18	0.83	0.570	0.401	
24 Feb. 67	0.22	13.7	0.58	0.49	5.67	4.80	
10 Mar. 67	1.34	31.0	1.40	1.13	0.993	0.80	0.774
15 Mar. 67	0.74	34.8	0.85	0.64	0.970	0.731	
Totals	8.34		14.2	7.37			
Flow-weighted Means		59.2			0.846	0.440	

TABLE E-1 (cont'd)

MASS DISCHARGE RELATIONSHIPS FOR
SELBY STREET OUTFALL

CONSTITUENT: Phosphate

Date of Storm	Rainfall (in)	Runoff Factor (percent)	Mass Discharge (10^3 lb)		Mass Discharge Factor (lbs per Acre-Inch of Runoff)		
			Total	Due to Storm	Total	Due to Storm	
6 Nov. 66	0.98	35.8	0.590	0.336	0.49	0.279	
14 Nov. 66	0.42	59.6	0.061	0.007			
15 Nov. 66			0.348	0.176			
20 Jan. 67	3.92	81.3	1.382	0.327	0.128	0.030	
23 Jan. 67	0.72	84.6	0.362	0.276	0.175	0.133	
24 Feb. 67	0.22	13.7	0.073	0.040	0.715	0.392	
10 Mar. 67	1.34	31.0	0.118	0.052	0.084	0.037	0.111
15 Mar. 67	0.74	34.8	0.250	0.199	0.286	0.228	
Totals	8.34		3.184	1.413			
Flow-weighted Means		59.2			0.190	0.084	

TABLE E-2

MASS DISCHARGE RELATIONSHIPS FOR LAGUNA STREET OUTFALL

Date of Storm	Rainfall (in)	Runoff Factor (percent)	Mass Discharge (10^3 lb) Total	Mass Discharge (10^3 lb) Due to Storm	Mass Discharge Factor (lbs per Acre-Inch of Runoff) Total	Mass Discharge Factor (lbs per Acre-Inch of Runoff) Due to Storm
CONSTITUENT: BOD						
10 Mar. 67	1.01	34.6	1.89	1.24	15.46	10.14
15 Mar. 67	0.813	47.3	1.63	0.88	12.10	6.54
Totals	1.823		3.52	2.12		
Flow-weighted Means		40.2			13.70	8.26
Adjusted Means		70			9.50	4.04
CONSTITUENT: COD						
10 Mar. 67	1.01	34.6	5.40	3.82	44.1	31.2
15 Mar. 67	0.813	47.3	4.46	2.60	33.2	19.3
Totals	1.823		9.86	6.42		
Flow-weighted Means		40.2			38.5	25.0
Adjusted Means		70			33.5	20.0
CONSTITUENT: Suspended Solids						
10 Mar. 67	1.01	34.6	10.56	9.93	86.3	81.1
15 Mar. 67	0.813	47.3	5.02	4.27	37.3	31.75
Totals	1.823		15.58	14.20		
Flow-weighted Means		40.2			60.9	55.5
Adjusted Means		70			37.5	32.1

TABLE E-2 (cont'd)

Date of Storm	Rainfall (in)	Runoff Factor (percent)	Mass Discharge (10^3 lb)		Mass Discharge Factor (lbs per Acre-Inch of Runoff)	
			Total	Due to Storm	Total	Due to Storm
CONSTITUENT: Volatile Suspended Solids						
10 Mar. 67	1.01	34.6	4.08	3.55	33.40	29.0
15 Mar. 67	0.813	47.3	2.74	2.11	20.35	15.68
Totals	1,823		6.82	5.66		
Flow-weighted Means		40.2			25.83	21.45
Adjusted Means		70			15.6	10.8
CONSTITUENT: Floatables						
10 Mar. 67	1.01	34.6	0.152	0.136	1.24	1.11
15 Mar. 67	0.813	47.3	0.05	0.032	0.372	0.238
Totals	1.823		0.202	0.168		
Flow-weighted Means		40.2			0.79	0.65
Adjusted Means		70				
CONSTITUENT: Grease						
10 Mar. 67	1.01	34.6	0.87	0.71	7.11	5.80
15 Mar. 67	0.813	47.3	0.43	0.29	3.20	2.155
Totals	1,823		1.30	1.00		
Flow-weighted Means		40.2			5.07	3.90
Adjusted Means		70			2.83	1.66

TABLE E-2 (cont'd)

Date of Storm	Rainfall (in)	Runoff Factor (percent)	Mass Discharge (10^3 lb) Total	Mass Discharge (10^3 lb) Due to Storm	Mass Discharge Factor (lbs per Acre-Inch of Runoff) Total	Mass Discharge Factor (lbs per Acre-Inch of Runoff) Due to Storm
CONSTITUENT: Total Nitrogen						
10 Mar. 67	1.01	34.6	0.176	0.083	1.44	0.679
15 Mar. 67	0.813	47.3	0.163	0.057	1.21	0.423
Totals	1.823		0.339	0.140		
Flow-weighted Means		40.2			1.33	0.545
Adjusted Means		70			1.09	0.31
CONSTITUENT: Phosphate						
10 Mar. 67	1.01	34.6	0.024	Neg.	0.196	-
15 Mar. 67	0.813	47.3	0.036	0.006	0.268	0.0445
Totals	1.823		0.060	0.006		
Flow-weighted Means		40.2			0.234	0.0234
Adjusted Means		70			0.229	0.018

APPENDIX F

RECEIVING WATER COLIFORM DATA

TABLE F-1

CONFIRMED COLIFORM MPN'S IN LAGUNA RECEIVING WATERS
MARCH 1967

Date and Period		Station 1	2	3	4	5	6	7
11	Evening	23	23	6	< 2.3	23	6	13
12	Morning	23	240	700	240	700	23	62
	Evening	240	700	23	23	> 2400	6	23
13	Morning	700	> 2400	> 2400	> 2400	240	6	240
	Evening	130	240	240	6	700	23	23
14	Morning	6	62	6	62	23	23	23
	Evening	6	23	6	62	62	62	6
15	Morning	23	62	23	23	50	23	6
	Evening	6	23	6	6	< 2.3	23	< 2.3
16	Morning	23	240	23	23	23	6	6
	Evening	23	23	23	23	23	23	6
17	Morning	6	20	6	50	62	23	6
	Evening	< 2.3	6	< 2.3	6	6	62	23
18	Morning	62	62	23	62	240	1.3	23
	Evening	6	23	23	6	23	6	23
19	Morning	23	13	6	23	< 2.3	6	23

TABLE F-2

FECAL COLIFORM MPN'S IN LAGUNA RECEIVING WATERS
MARCH 1967

Date and Period		Station 1	2	3	4	5	6	7
11	Evening	6	6	6	< 2.3	23	< 2.3	6
12	Morning	6	4.6	62	23	240	6	23
	Evening	240	62	23	6	23	< 2.3	6
13	Morning	700	> 2400	> 2400	> 2400	240	< 2.3	62
	Evening	62	23	23	6	62	23	6
14	Morning	< 2.3	< 2.3	< 2.3	< 2.3	< 2.3	6	6
	Evening	< 2.3	23	6	6	4.6	< 2.3	< 2.3
15	Morning	< 2.3	6	6	< 2.3	6	6	< 2.3
	Evening	6	6	< 2.3	6	< 2.3	6	< 2.3
16	Morning	23	240	< 2.3	6	6	6	< 2.3
	Evening	6	23	6	6	< 2.3	< 2.3	6
17	Morning	< 2.3	4.5	< 2.3	12	6	23	< 2.3
	Evening	< 2.3	6	< 2.3	6	< 2.3	< 2.3	< 2.3
18	Morning	13	23	6	< 2.3	13	6	6
	Evening	< 2.3	< 2.3	6	< 2.3	6	< 2.3	< 2.3
19	Morning	6	< 2.3	6	6	< 2.3	< 2.3	6